



US006951162B1

(12) **United States Patent**
Shockey et al.

(10) **Patent No.:** **US 6,951,162 B1**
(45) **Date of Patent:** **Oct. 4, 2005**

(54) **PENETRATION-AND FIRE RESISTANT FABRIC MATERIALS AND STRUCTURES**

5,806,796 A * 9/1998 Healey 244/117 R
6,119,575 A * 9/2000 Dragone et al. 89/36.05

(75) Inventors: **Donald A. Shockey**, Menlo Park, CA (US); **David C. Erlich**, Palo Alto, CA (US); **Jeffrey W. Simons**, Palo Alto, CA (US)

FOREIGN PATENT DOCUMENTS

FR 1054606 * 2/1954 244/129.1
FR 2 653 090 * 4/1991 244/119
JP 2-37100 * 2/1990 244/121
JP 2-183798 * 7/1990 89/36.02

(73) Assignee: **SRI International**, Menlo Park, CA (US)

OTHER PUBLICATIONS

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

English translation of Japan 2-183798; 10 pages.*
DuPont; Kevlar Aramid; Dec. 9; 1982; 428/911; pp. 1-8.*

* cited by examiner

(21) Appl. No.: **09/544,357**

Primary Examiner—Stephen M. Johnson
(74) *Attorney, Agent, or Firm*—Perkins Coie LLP

(22) Filed: **Apr. 6, 2000**

(57) **ABSTRACT**

Related U.S. Application Data

(63) Continuation of application No. 09/325,596, filed on Jun. 2, 1999, now Pat. No. 6,612,217.

(60) Provisional application No. 60/087,771, filed on Jun. 2, 1998.

(51) **Int. Cl.**⁷ **B64D 7/00**

(52) **U.S. Cl.** **89/36.11**; 89/36.02; 244/121

(58) **Field of Search** 89/36.01, 36.02, 89/36.11; 244/119, 129.1, 123, 121, 125, 126

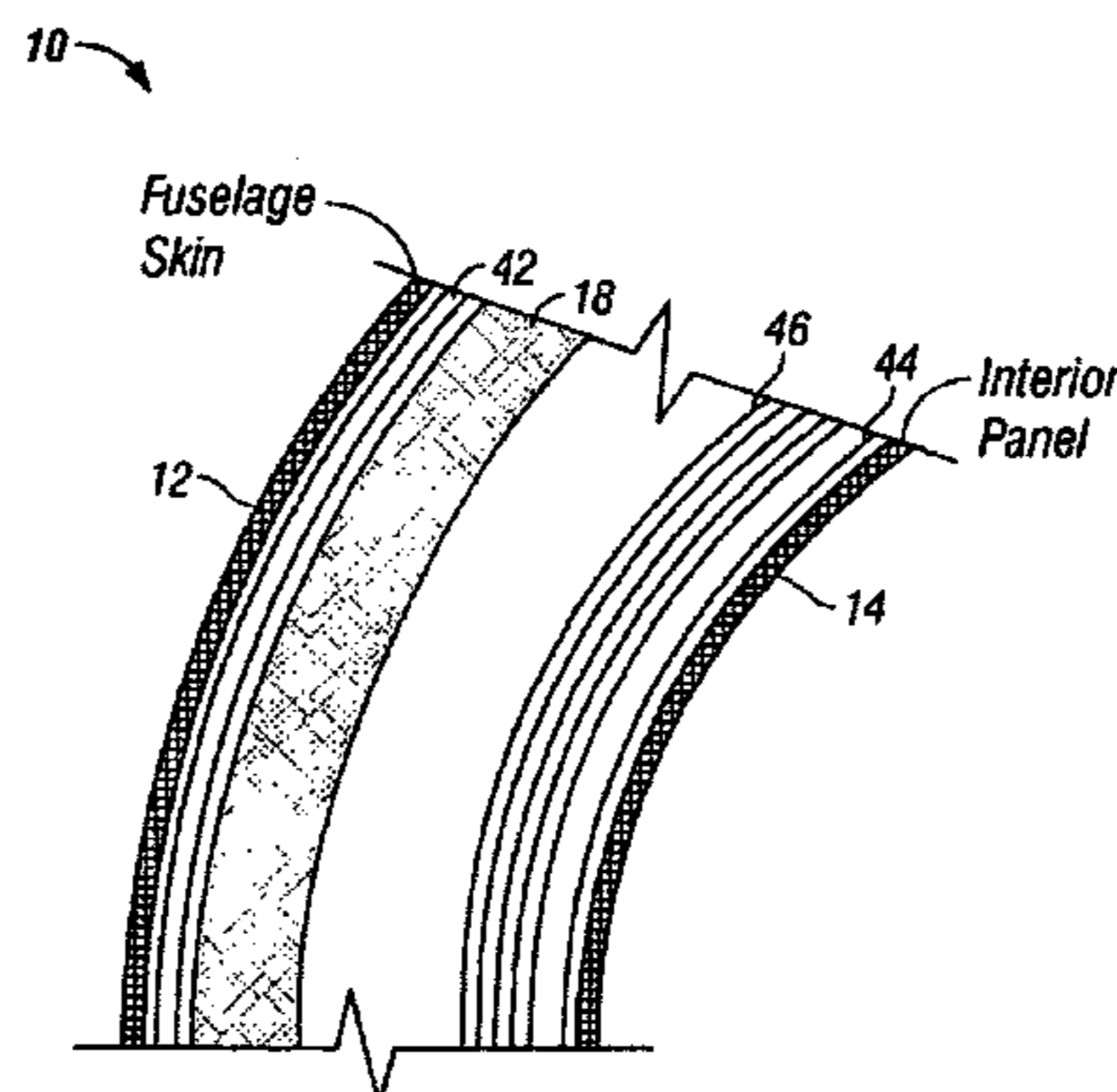
A ballistic and/or fire barrier for protecting objects in an interior of a vehicle due to projectile penetration and/or fire includes one or more layers of high strength fabric positioned towards an outer shell of the vehicle. The high strength fabric is substantially fixedly or fixedly positioned with respect to the outer shell of the vehicle. In another embodiment, the ballistic and/or fire barrier protects objects in a structure from damage due to projectile penetration. The ballistic and/or fire barrier includes at least one layer of high strength fabric positioned towards an outer housing of the structure. The high strength fabric is substantially fixedly positioned with respect to the structure towards either the inner or outer surface of the outer housing. In another embodiment of the present invention, a ballistic barrier protects a wearer of the ballistic barrier from damage due to projectile penetration. The ballistic barrier comprises first and second portions positioned generally parallel each other. The first portion includes one or more layers of high strength fabric while the second portion is generally impact-resistant. Preferably, the layer of high strength fabric comprise a plurality of plies. One of the plies can comprise woven fibers. Another of the plies can be a felt. Also preferably, the layer of high strength fabric in the ballistic barrier embodiments comprises a polymer material such as one or more of aramid material, polyethylene material, and polybenzoxazole material.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,576,162 A * 4/1971 Lea 244/121
3,740,905 A * 6/1973 Adams 244/119
3,974,313 A * 8/1976 James 428/176
4,291,851 A * 9/1981 Johnson 244/119
4,404,889 A * 9/1983 Miguel 89/36.02
4,822,657 A * 4/1989 Simpson 428/69
5,031,862 A * 7/1991 Rhodes 244/121
5,102,723 A * 4/1992 Pepin 428/223
5,169,700 A * 12/1992 Meier et al. 428/921
5,398,889 A * 3/1995 White et al. 244/119
5,472,760 A * 12/1995 Norvell 244/119
5,520,132 A * 5/1996 Crippen 114/72
5,533,781 A * 7/1996 Williams 296/204
5,679,918 A * 10/1997 Korpi et al. 89/36.08
5,705,764 A * 1/1998 Schade et al. 89/36.02

20 Claims, 20 Drawing Sheets



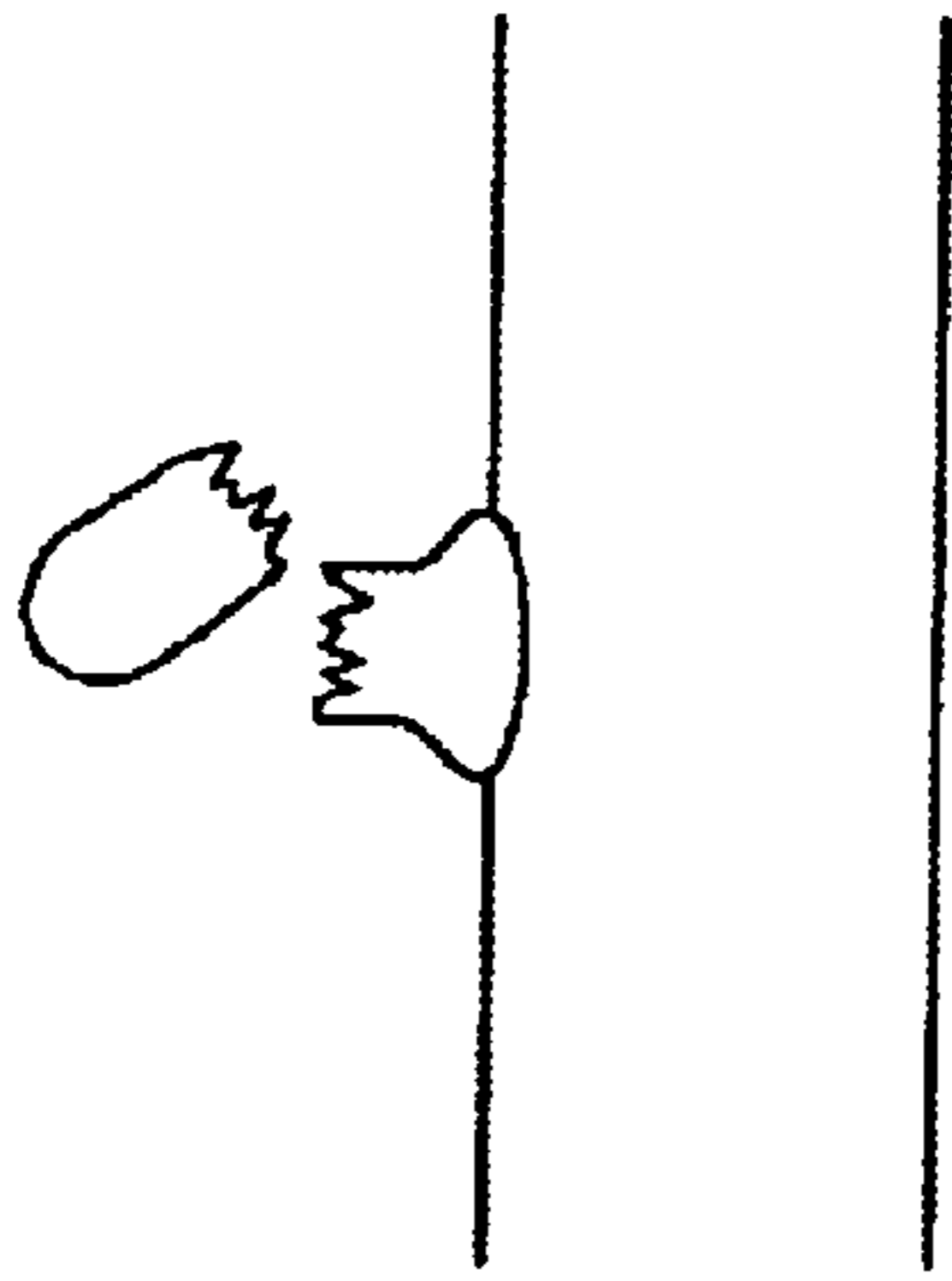


FIG. 1A

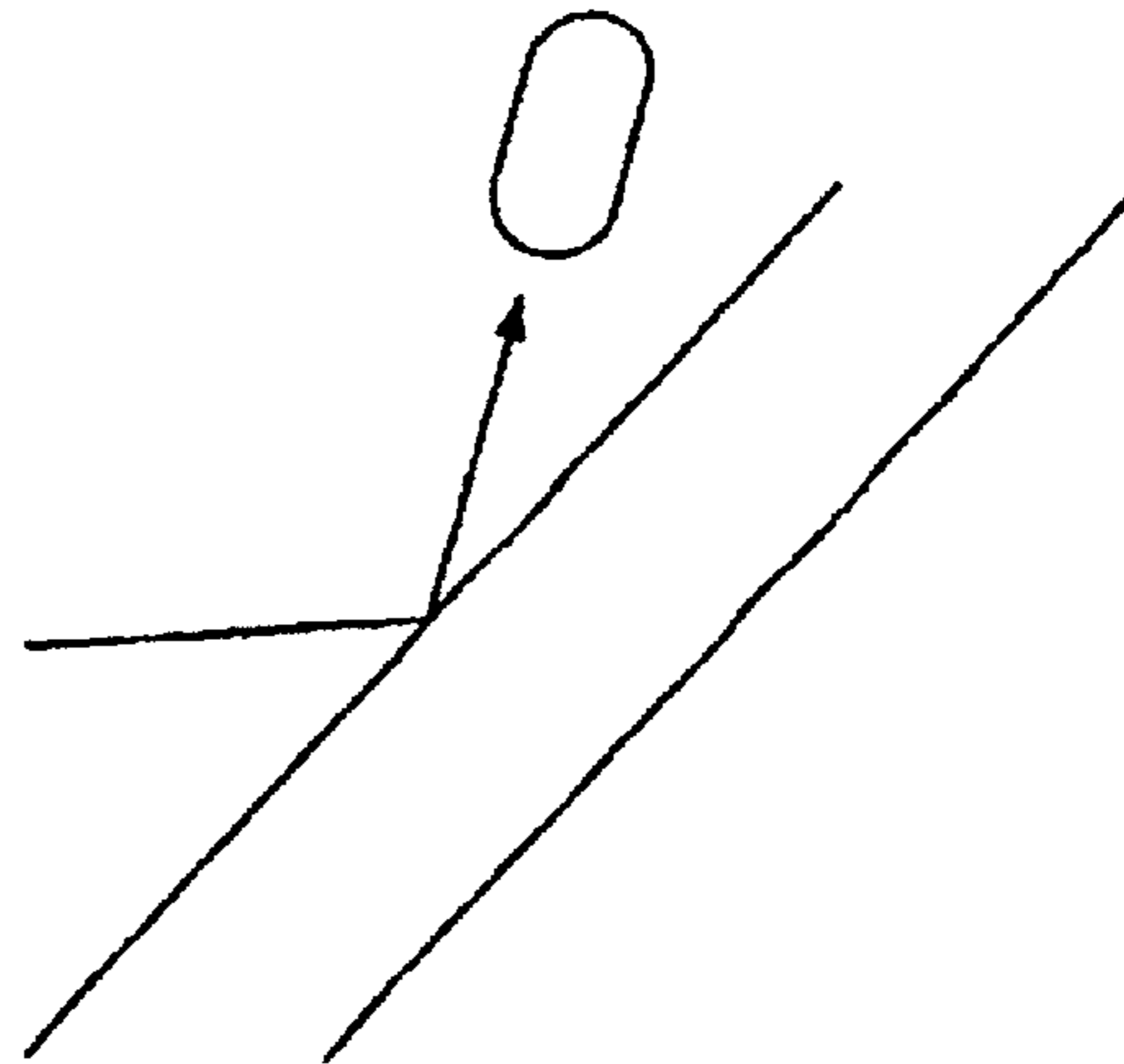


FIG. 1B

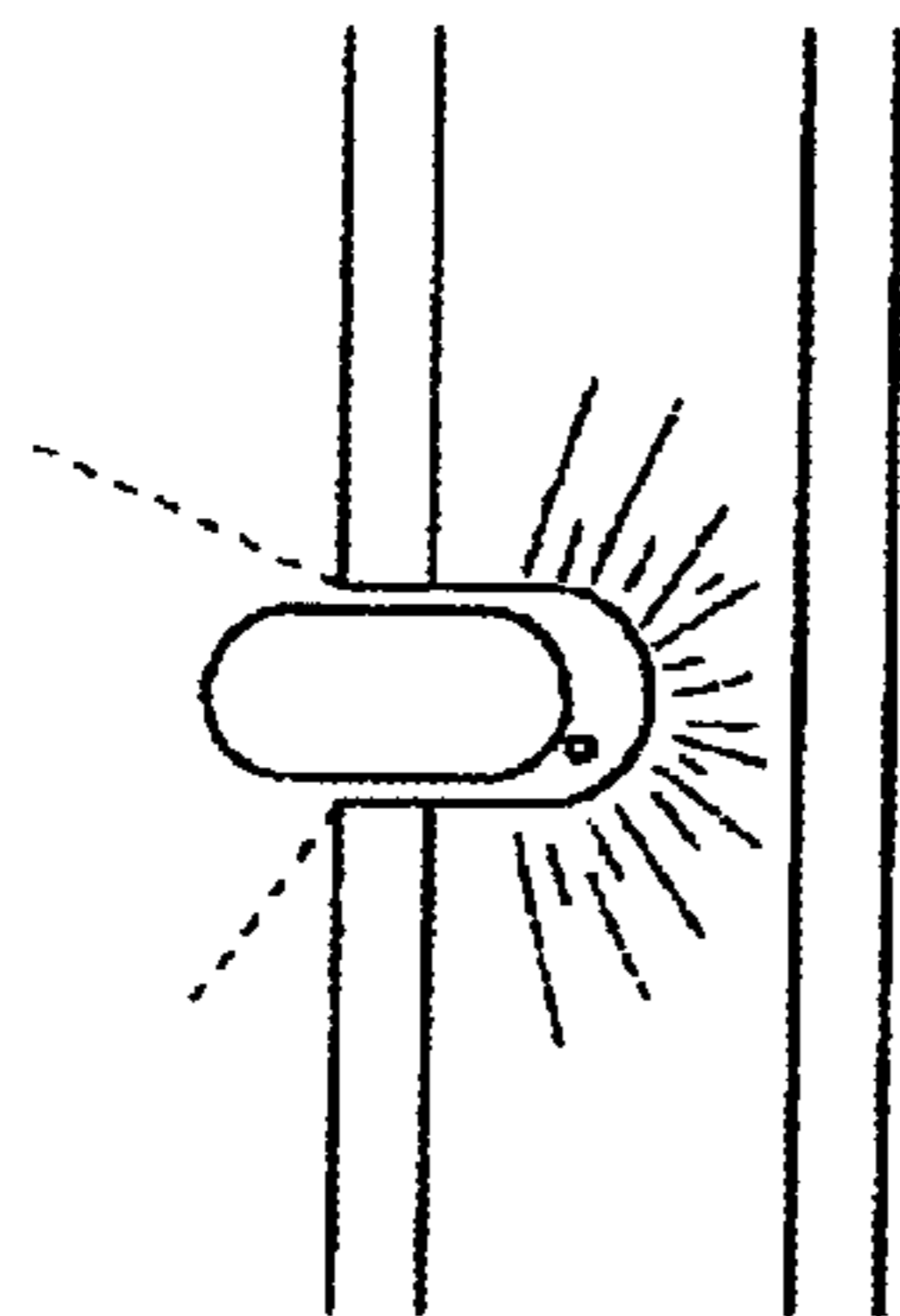


FIG. 1C

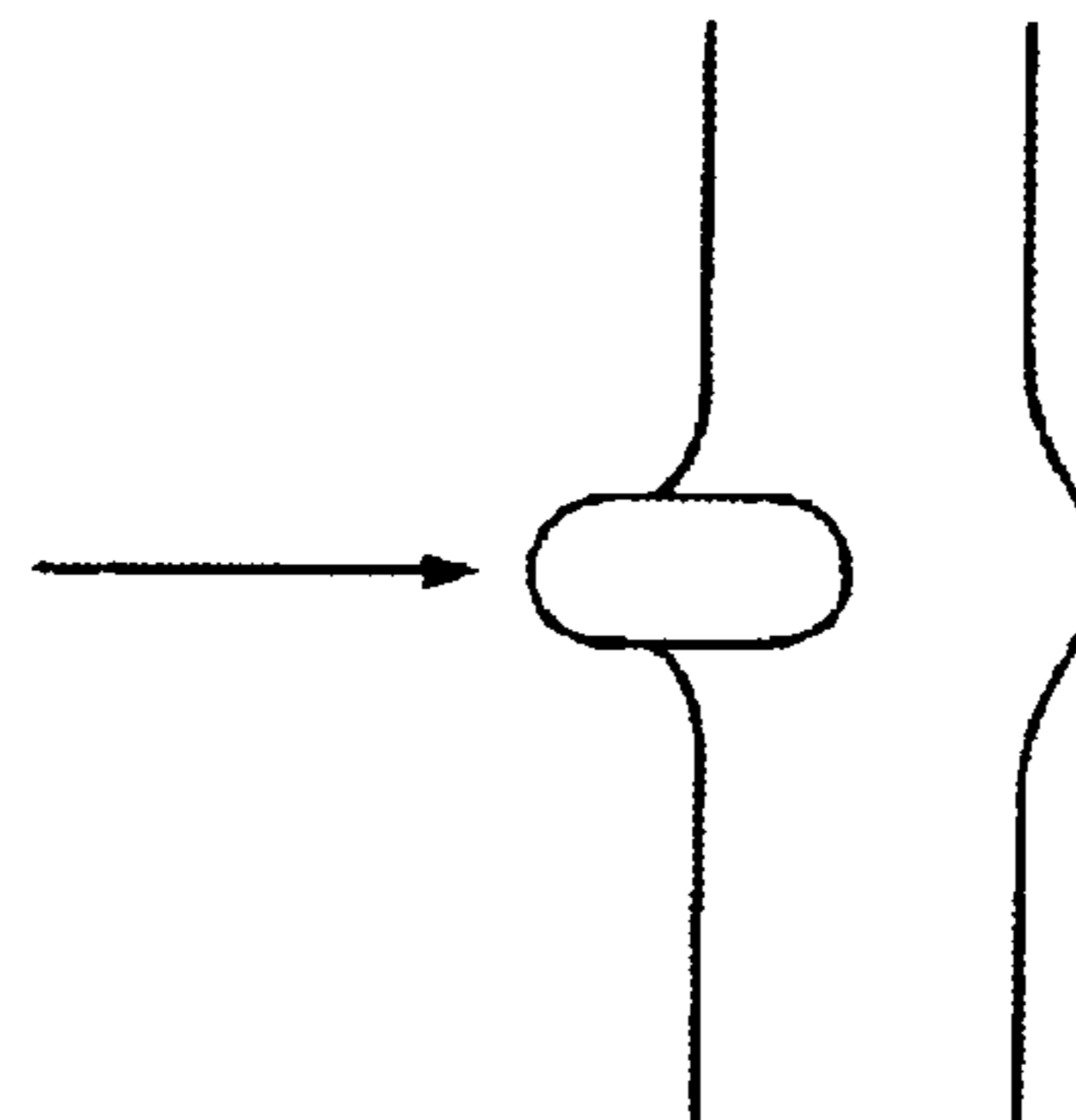


FIG. 1D

TEST NO.	TARGET				AREAL DENSITY (G/CM ²)	FS ^B : BEFORE IMPACT			FS: AFTER PENETRATION			SPECIFIC ENERGY ABSORBED ^C (J/G/CM ²)	
	MATERIAL(S)	MESH (YARNS/IN.)	THICKNESS PER PLY (IN.)	NO. OF PLYS		MASS (G)	VELOCITY (M/S)	K.E. (J)	VELOCITY (M/S)	K.E. (J)	K.E. LOST (%)		
20	ZYLON	30X30	≈0.006	1	0.0130	25	79	78	61.5	47.5	30.5	39	2346
26	ZYLON	30X30	≈0.006	1	0.0130	25	82.5	85	63	49.5	34.5	41	2654
23	ZYLON	30X30	≈0.006	1	0.0130	25	80	80	35.5 ^F	20 ^F	60	75	1366
	UHMW POLYETHYLENE FELT		≈0.13	1	+0.0309								
22	ZYLON	30X30	≈0.006	1	0.0130	25	82	84	DID NOT G PENETRATE			84	100
	UHMW POLYETHYLENE FELT		≈0.13	2	+0.0618								≥1123

^B FS MEANS FRAGMENT SIMULATOR.

^C SPECIFIC ENERGY ABSORBED (SEA) IS DEFINED AS ENERGY ABSORBED PER UNIT AREAL DENSITY.

^F THE IMPACTOR DID NOT PENETRATE THE FELT; HOWEVER, THE IMPACTOR, SURROUNDED BY THE FELT LAYER, COMPLETELY PENETRATED THE FABRIC.

^G ONLY PARTIAL PENETRATION WAS OBTAINED IN THIS TEST-THE IMPACTOR, SURROUNDED BY THE FELT, REMAINED LODGED IN THE HOLE IN THE FABRIC.

FIG. 2

TEST NO. A	TARGET			AREAL DENSITY (G/CM ²)	FS ^B : BEFORE IMPACT		FS : AFTER PENETRATION			SPECIFIC ENERGY ABSORBED (J/G/CM ²)			
	MATERIAL(S)	MESH (YARNS/IN.)	THICKNESS PER PLY (IN.)		NO. OF PLYS	MASS VELOCITY (M/S)	K.E. (J)	VELOCITY (M/S)	K.E. (J)		K.E. LOST (%)		
13	ZYLON	45X45	≈0.011	1	0.0219	25	78	76	10.5	65.5	86	2990	
19D	ZYLON	45X45	≈0.011	2	0.0438	25	113	160	51.5	108.5	68	2477	
20	ZYLON	30X30	≈0.006	1	0.0130	25	79	78	61.5	47.5	30.5	2346	
26	ZYLON	30X30	≈0.006	1	0.0130	25	82.5	85	63	49.5	34.5	2654	
25	ZYLON	35X35	≈0.0075	1	0.0158	25	77.5	75	59	43.5	37.5	2373	
24	ZYLON	40X40	≈0.009	1	0.0185	25	79	78	49.5	30.5	48.5	2622	
29	ZYLON	40X40	≈0.009	4	0.0740	96	79	300	27.5	36.5	263.5	3560	
32	ZYLON	40X40	≈0.009	6	0.111	96	79	300	DID NOT PENETRATE	300	100	2702	
23	ZYLON UHMW POLYETHYLENE FELT	30X30	≈0.006 ≈0.13	1 1	0.0130 +0.0309	25	80	80	35.5 ^F	20 ^F	60	75	—
22	ZYLON UHMW POLYETHYLENE FELT	30X30	≈0.006 ≈0.13	1 2	0.0130 +0.0618	25	82	84	DID NOT PENETRATE	DID NOT PENETRATE	84	100	—

A TESTS 13 AND 19 WERE PERFORMED AND REPORTED DURING THE PREVIOUS REPORTING YEAR.

B FRAGMENT SIMULATOR.

C SPECIFIC ENERGY ABSORBED (SEA) IS DEFINED AS ENERGY ABSORBED PER UNIT AREAL DENSITY.

D DATA FROM THIS TEST ARE QUESTIONABLE DUE TO THE EXCESSIVE PITCH, DEBRIS FROM THE ALUMINUM HONEYCOMB MOMENTUM TRAP TRAVELING AHEAD OF THE IMPACTOR, AND SOME P80 FIBERS FROM THE BACK (22° ORIENTATION) LAYER BREAKING AT THE CORNER OF THE CLAMPING ROD, AND THUS LIKELY REDUCING THE ABSORBED KINETIC ENERGY.

E THE IMPACTOR PENETRATED ONLY THE FIRST OF THE SIX LAYERS.

F THE IMPACTOR DID NOT PENETRATE THE FELT, HOWEVER, THE IMPACTOR, SURROUNDED BY THE FELT LAYER, COMPLETELY PENETRATED THE FABRIC.

G ONLY PARTIAL PENETRATION WAS OBTAINED IN THIS TEST-THE IMPACTOR, SURROUNDED BY THE FELT, REMAINED LODGED IN THE HOLE IN THE FABRIC.

FIG. 3

TEST NO.	VIDEO	TEST DATE (1998)	TARGET MATERIAL FABRIC TYPE (YARN COUNT)	NO. PLYS	AREAL DENSITY (G/CM ²)	GRIPPED EDGES ^A II TO WIDTH. NO. YARNS: (IN.)	PENETRATOR		STROKE RATE ^D (IN./S)	DATA RATE (MS)	1ST YARN BREAK		FAILURE STROKE (IN.)	MAXIMUM		YARNS BROKEN (WARP + FILL)	WORK DONE (IN-LB)	PER BROKEN YARN (J)	SEA (J/G/CM ²)
							TYPE ^B	ORIENTATION ^C			LOAD (LB)	STROKE (IN.)		LOAD (LB)	MODULUS (LB/IN)				
P-22	✓	4/23	ZYLON 35X35 WEAVE	1	0.0158	4 W & F 5.0	29-G FB	45°	0.075	10	0.488	153	742	33+38=71	42	5	0.07	300	
P-23	✓	4/23	ZYLON 35X35 WEAVE ZYLON FELT #2	2	0.0160	NOT GRIPPED	29-G FB	45°	0.075	10	0.697	493	2545	35+36=71	220	25	0.35	782	
P-26	✓	4/28	ZYLON 35X35 WEAVE ZYLON FELT #2	1	0.0158	4 W & F 5.0	29-G FB	45°	0.075	10	0.672	400	1778	32+37=69	208	23	0.34	987	
P-28	✓	4/29	ZYLON 35X35 WEAVE	1	0.0158	2 F 5.0	29-G FB	45°	0.075	10	0.687	260	954	26+42=68	174	20	0.29	1244	
P-29	✓	4/30	ZYLON 35X35 WEAVE ZYLON FELT #2	2	0.0160	NOT GRIPPED	29-G FB	45°	0.075	10	0.781	398	1585	2+33=35	687	78	2.22	2441	
P-30	✓	5/7	ZYLON 35X35 WEAVE	1	0.0158	2 F 5.0	ROUNDED FB	45°	0.075	10	0.612	214	829	29+41=70	120	14	0.19	858	
P-31	✓	5/7	ZYLON 35X35 WEAVE ZYLON FELT #2	2	0.0160	NOT GRIPPED	ROUNDED FB	45°	0.075	10	0.834	463	1301	2+31=33	661	75	2.26	2348	
P-35	✓	5/13	ZYLON 35X35 WEAVE	1	0.0158	2 F 5.0	29-G FB	0°	0.075	10	0.667	288	1127	1+53=54	106	12	0.22	758	
P-36	✓	5/14	ZYLON 35X35 WEAVE ZYLON FELT #2	2	0.0160	NOT GRIPPED	29-G FB	0°	0.075	10	0.764	388	1773		943	107		3350	
P-37	✓	5/20	ZYLON 35X35 WEAVE	1	0.0158	2 F 5.0	25-G FS-SH	0°	0.075	10	0.572	240	974		81	9		579	
P-38	✓	5/20	ZYLON 35X35 WEAVE ZYLON FELT #2	2	0.0160	NOT GRIPPED	25-G FS-SH	0°	0.075	10	0.792?	377?	1475		433	49		1538	

A W=WARP YARNS; F= FILL YARNS.

B FS= FRAGMENT SIMULATOR; FB= FAN BLADE

C THE ANGLE BETWEEN THE DIRECTION OF THE WARP YARNS AND THE LONGEST DIMENSION OF THE PENETRATOR'S IMPACT END (e.g. THE BLADE DIRECTION).

D TESTS INVOLVE CONSTANT STROKE RATE TO COMPLETE PENETRATION, EXCEPT WHERE MARKED "C" (CYCLICAL LOADING) OR "I" (INTERRUPTED BEFORE FULL PENETRATION)

E DATA IS FOR COMPLETE PENETRATION, EXCEPT FOR INTERRUPTED TESTS (MARKED "I"), WHERE DATA IS AT MAXIMUM BEFORE INTERRUPTION.

F EQUALS THE AREA UNDER THE LOAD-DEFLECTION CURVE

FIG. 4

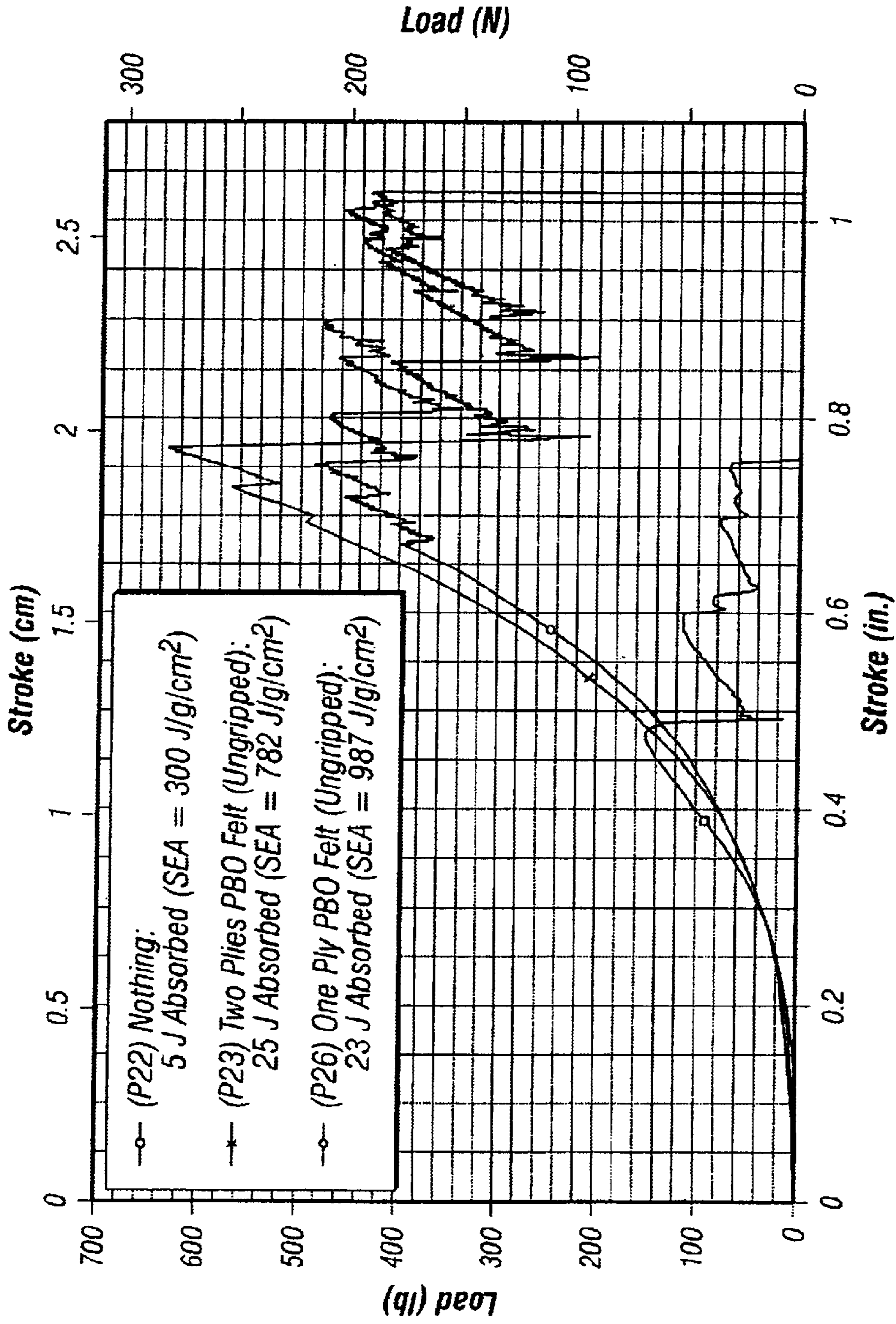


FIG. 5

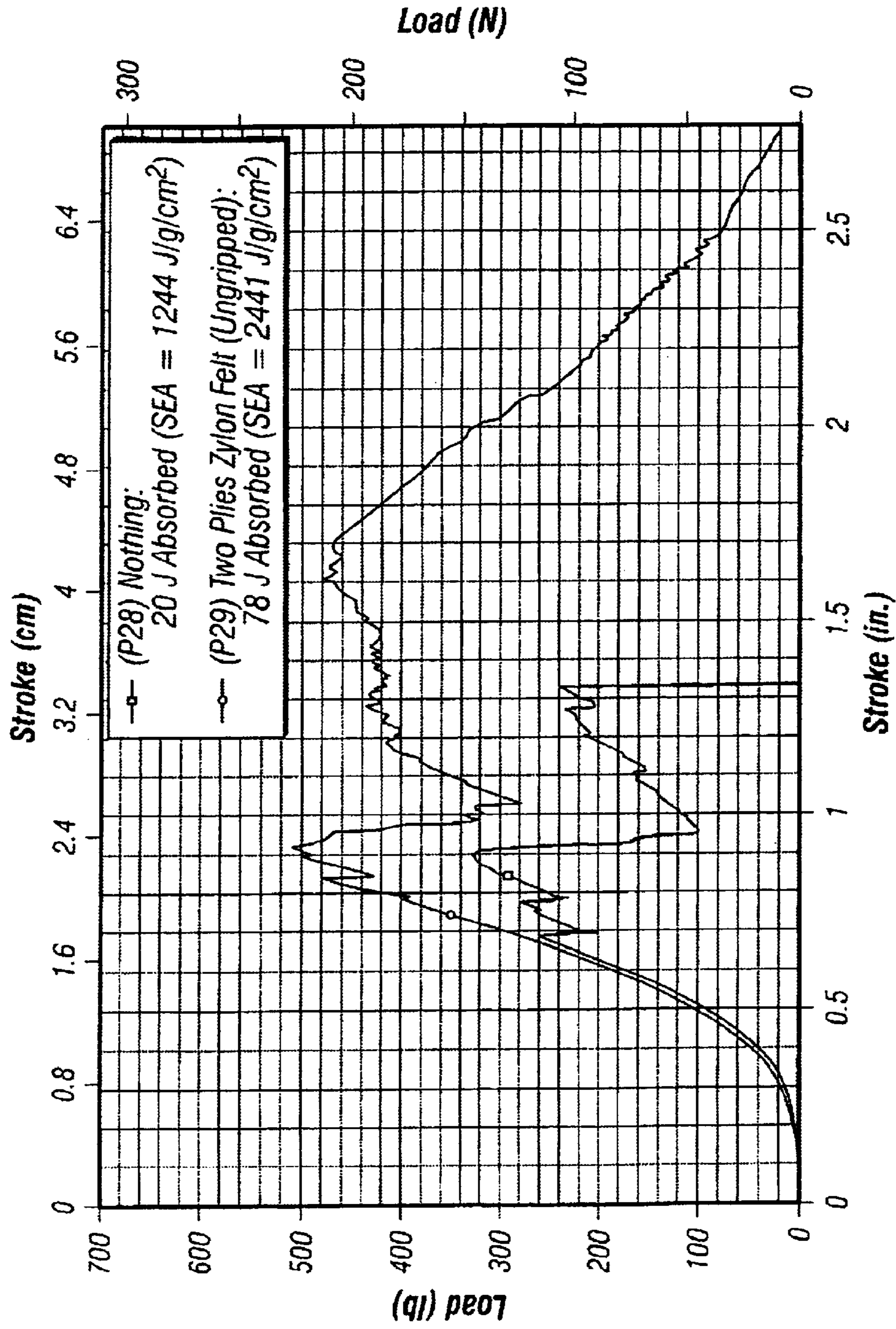


FIG. 6

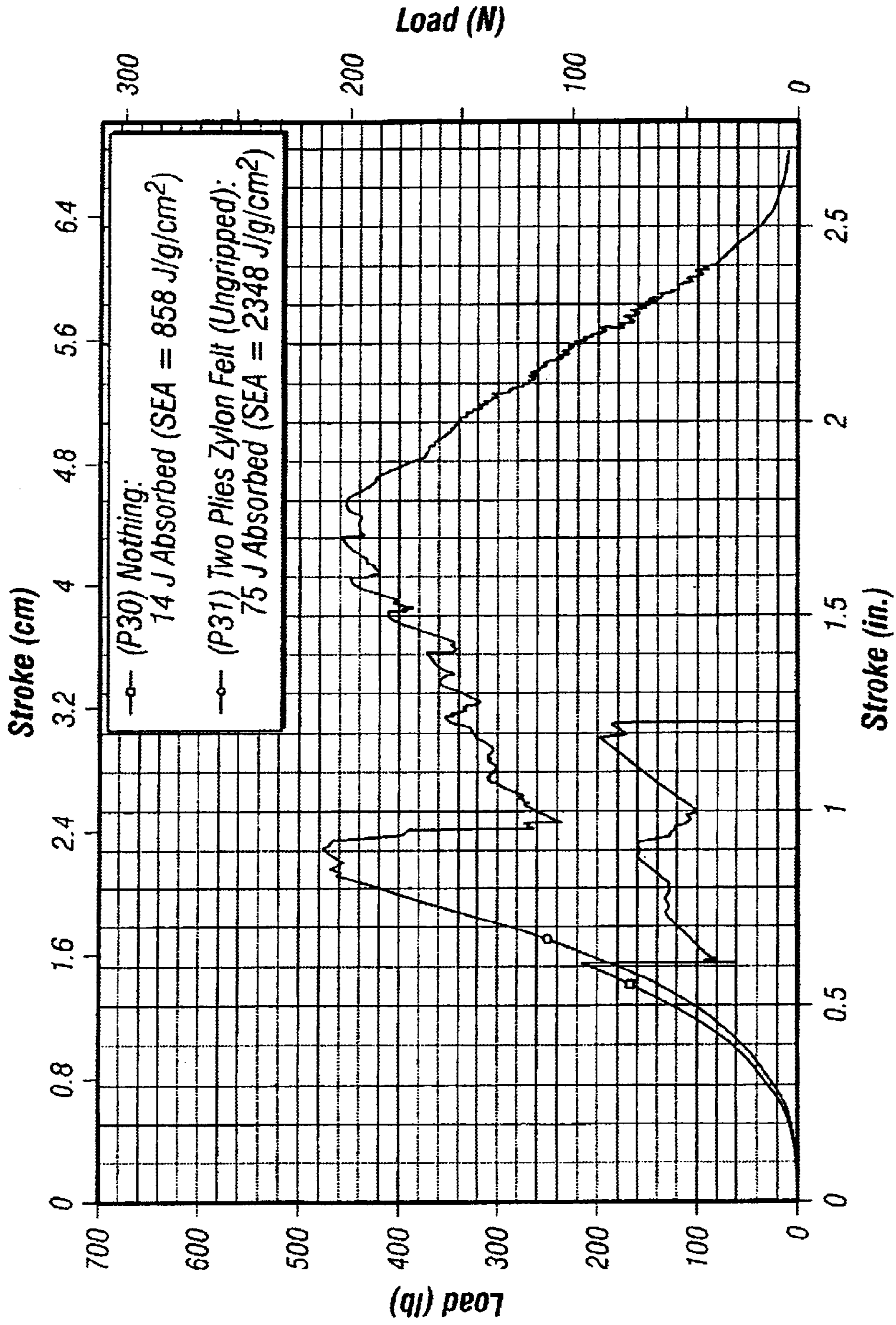


FIG. 7

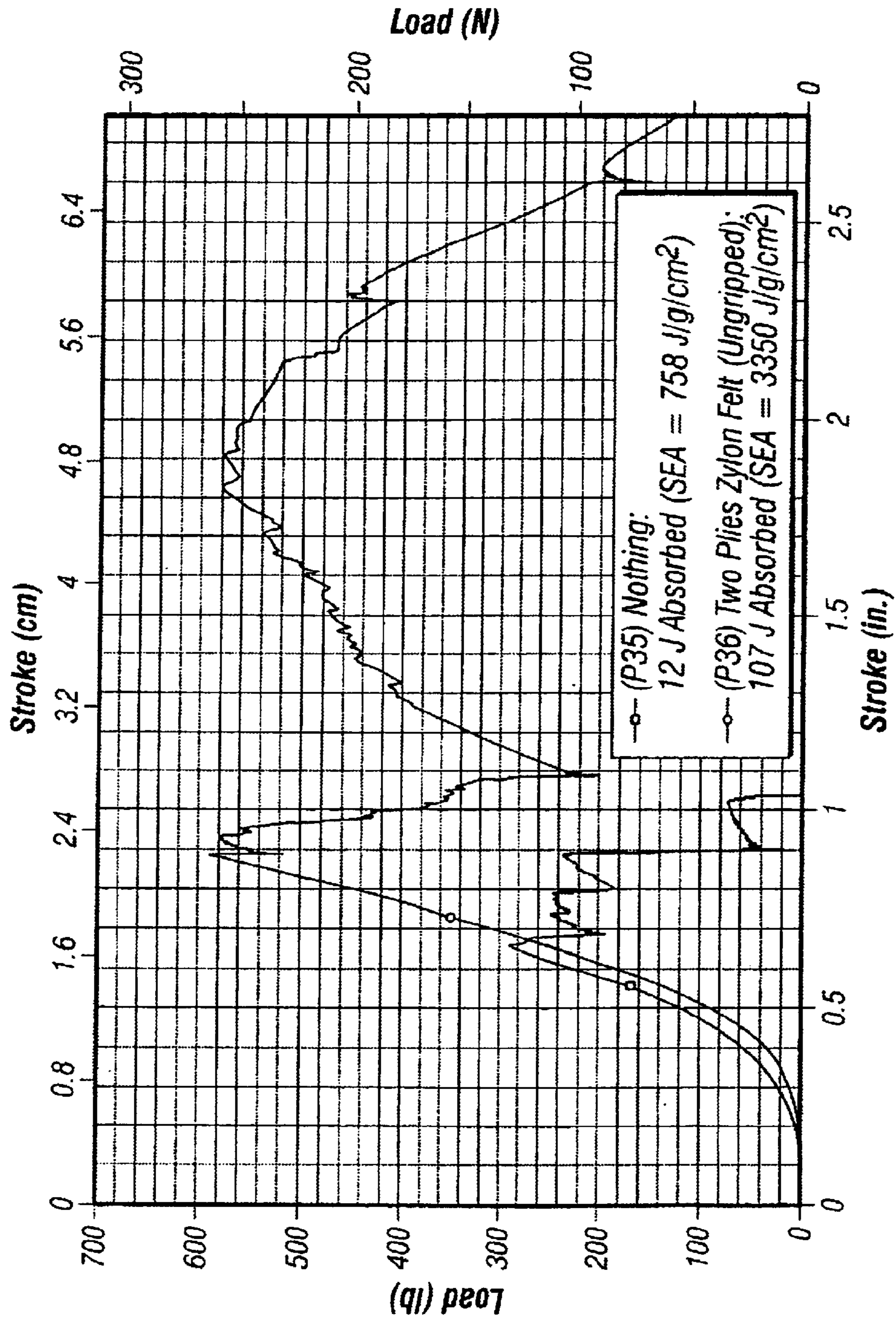


FIG. 8

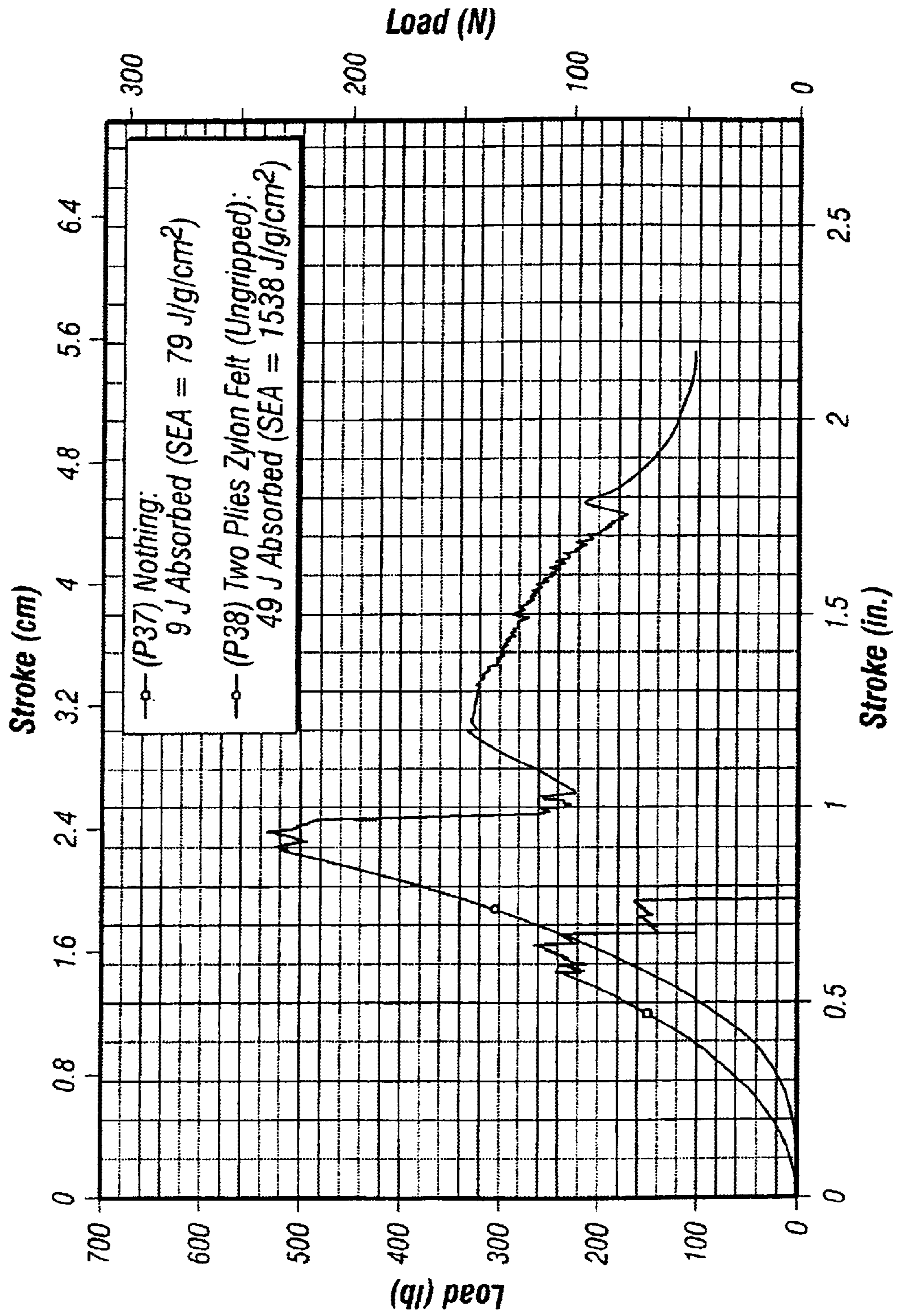


FIG. 9

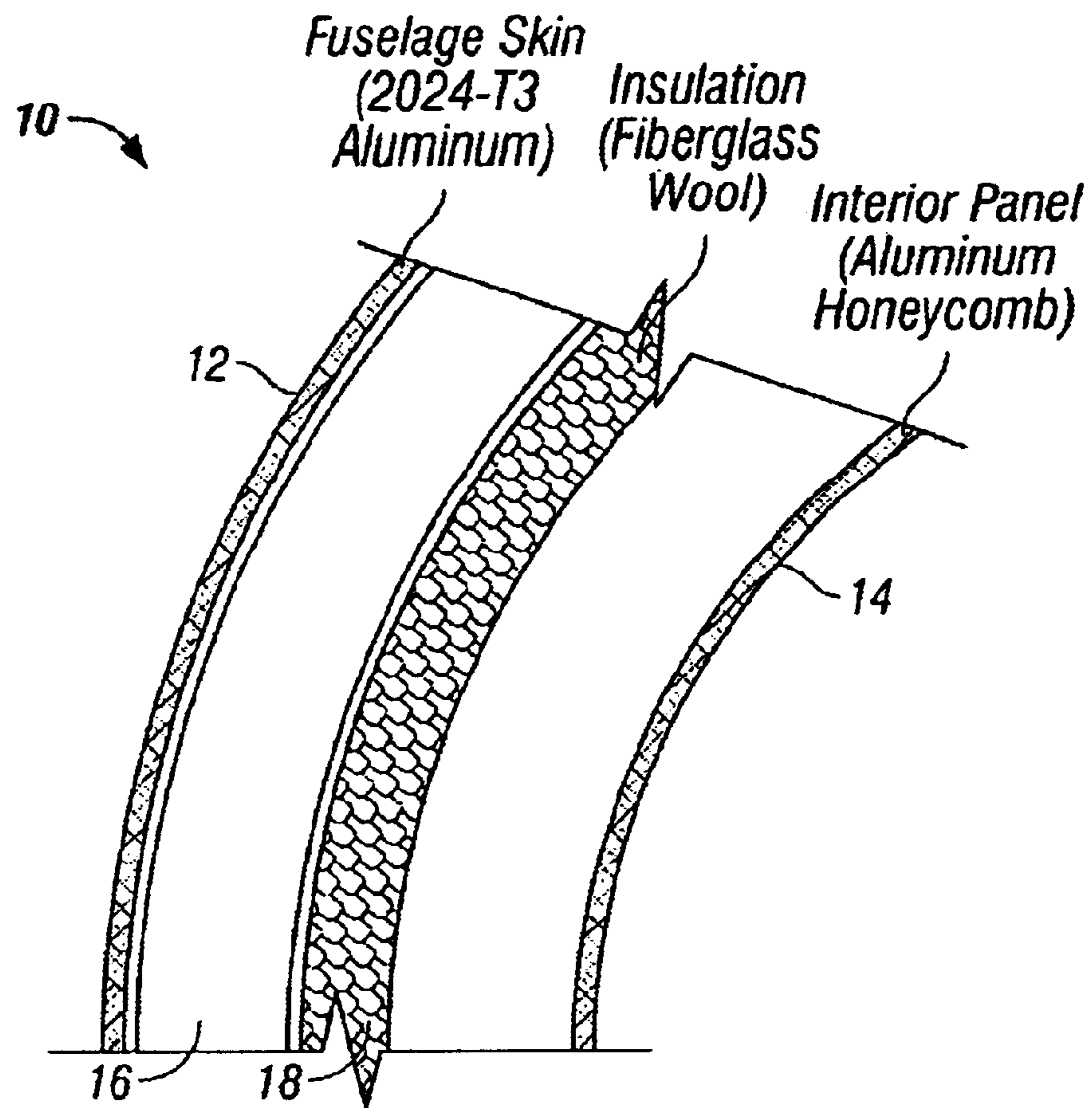


FIG. 10

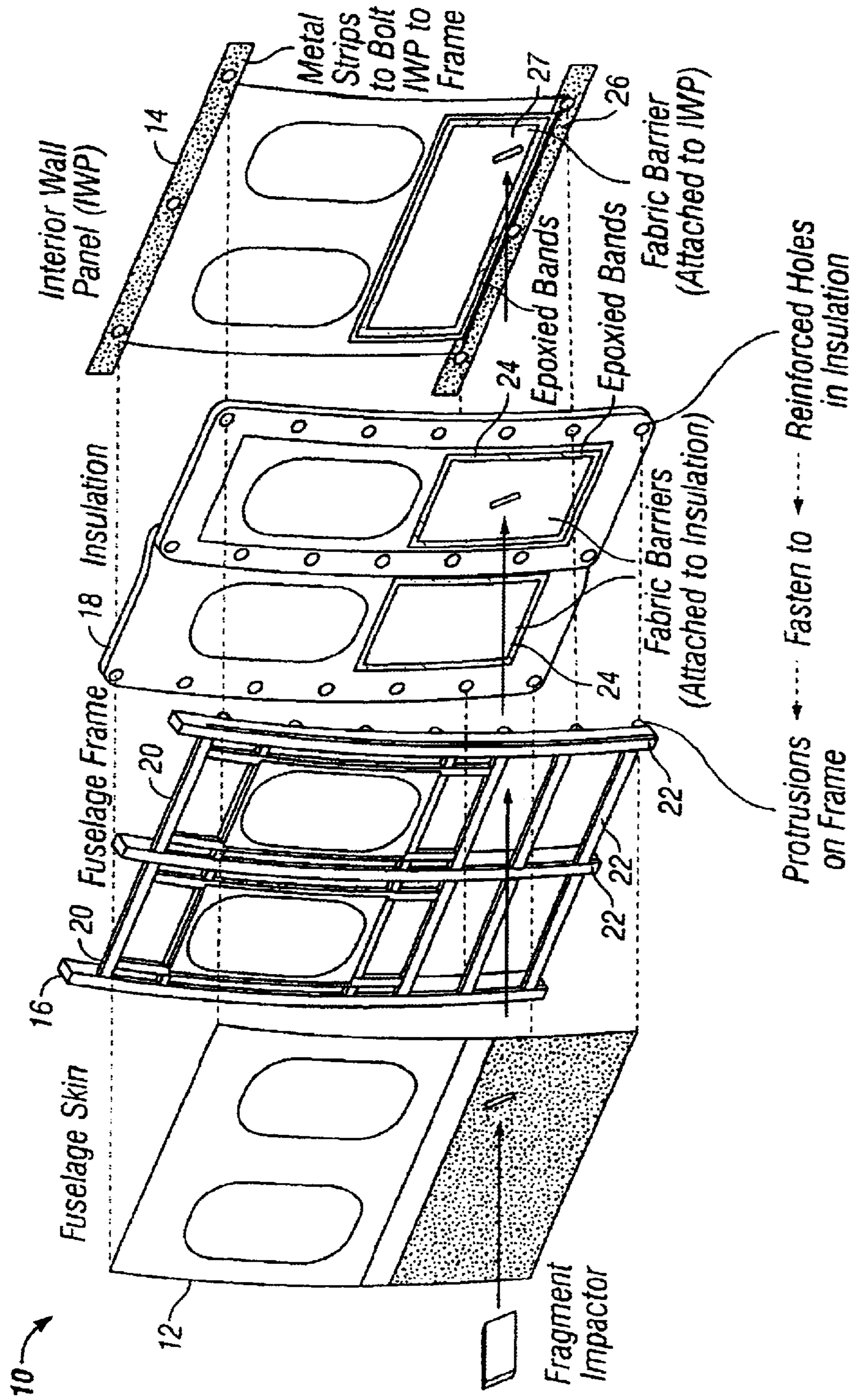


FIG. 11

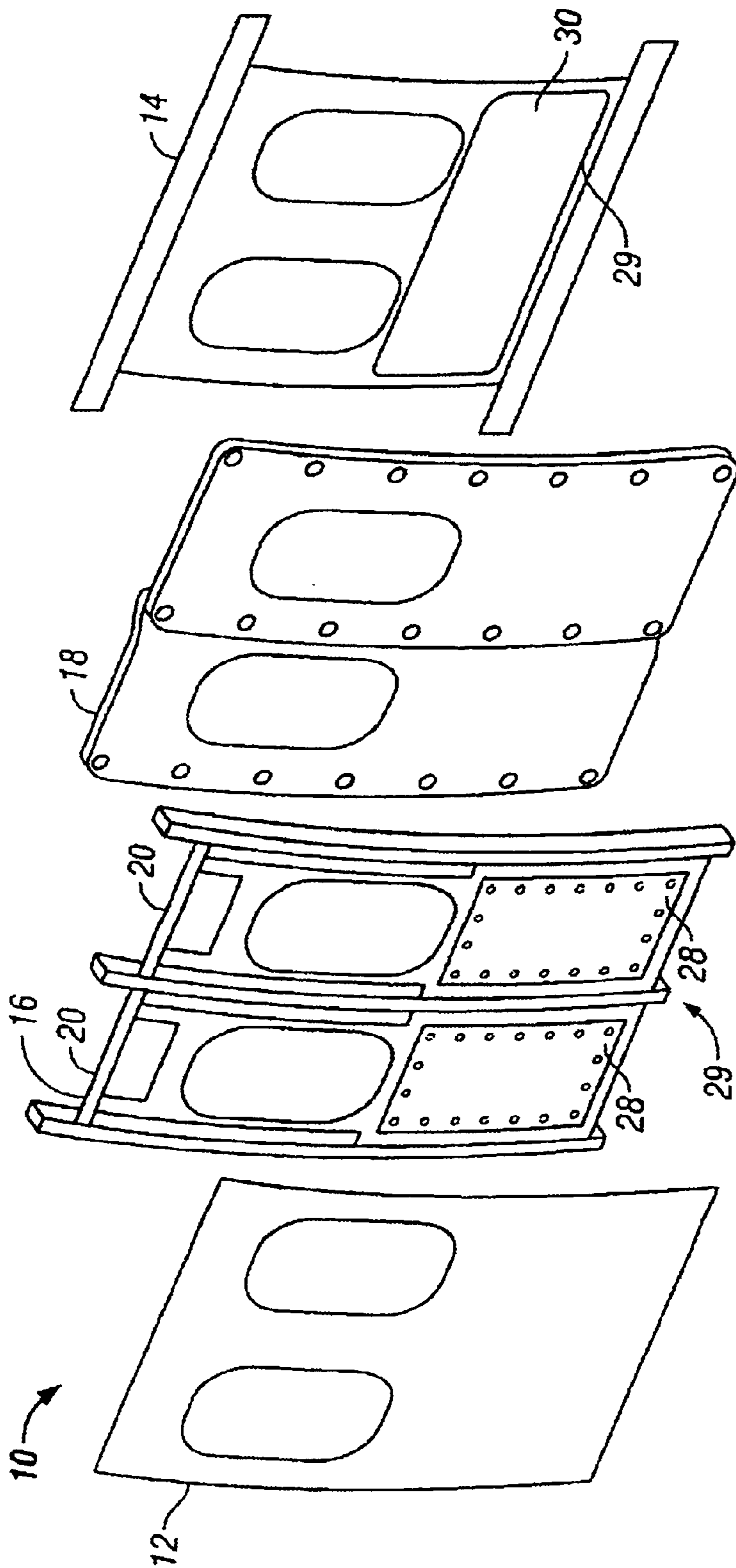


FIG. 12

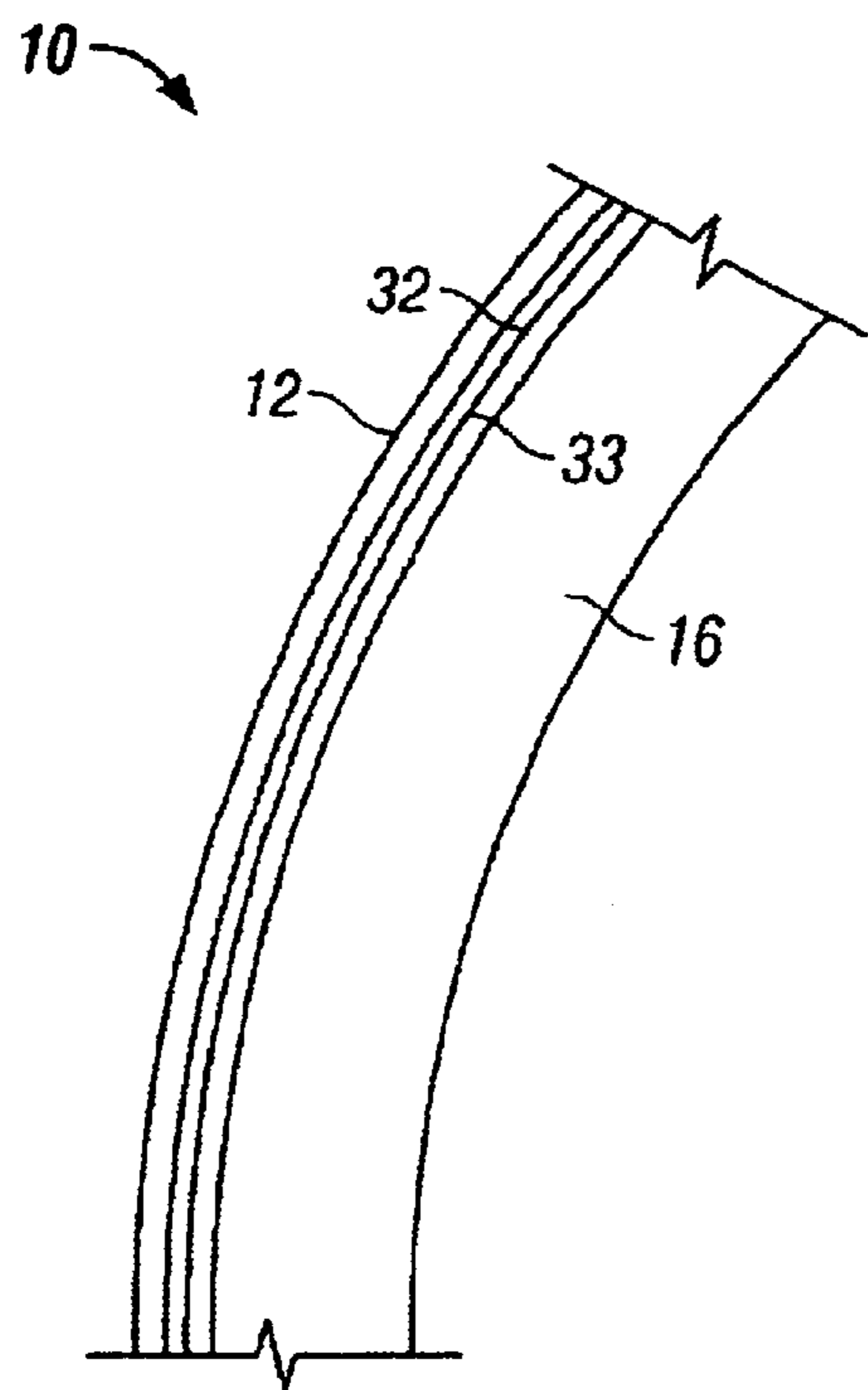


FIG. 13

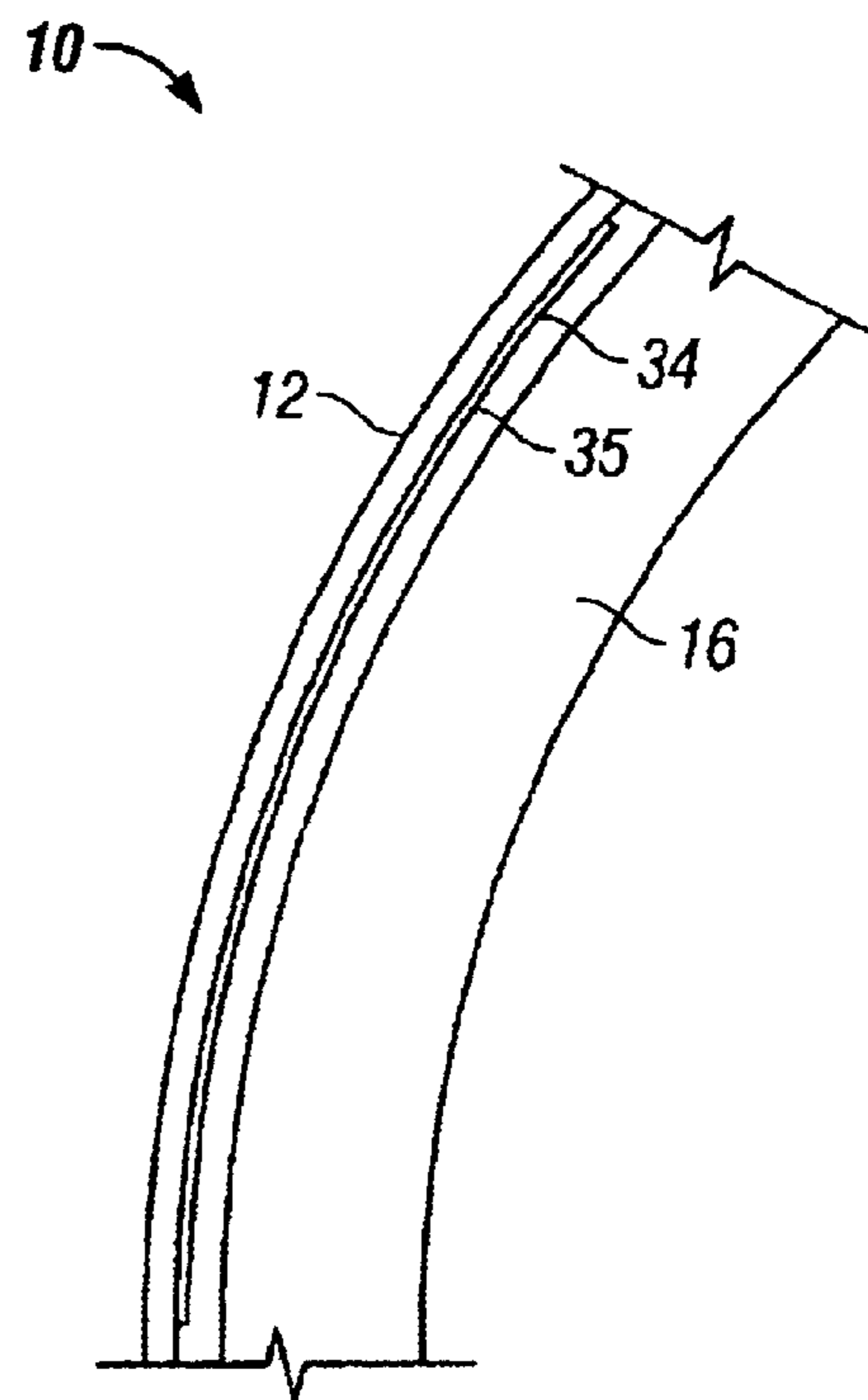


FIG. 14

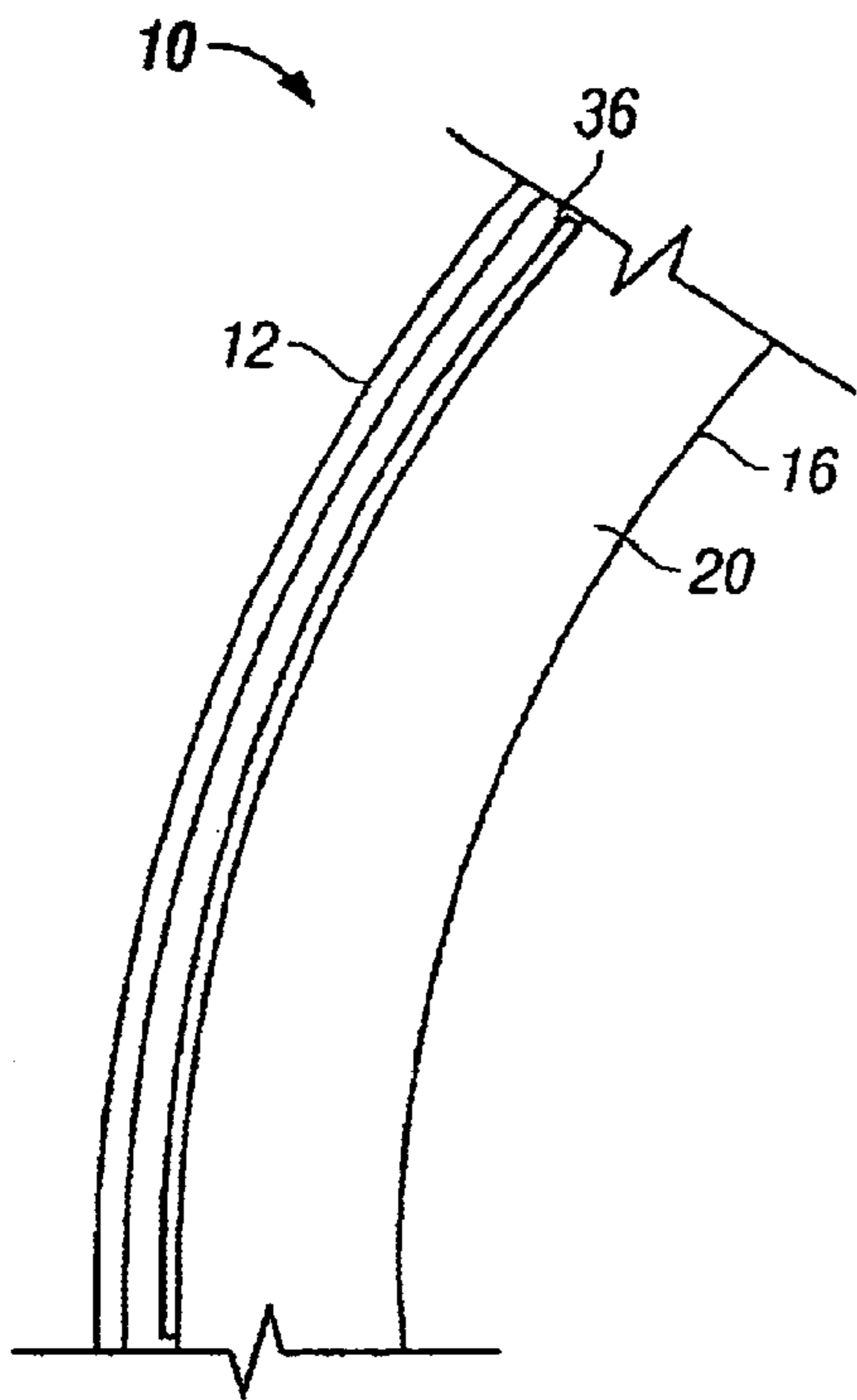


FIG. 15

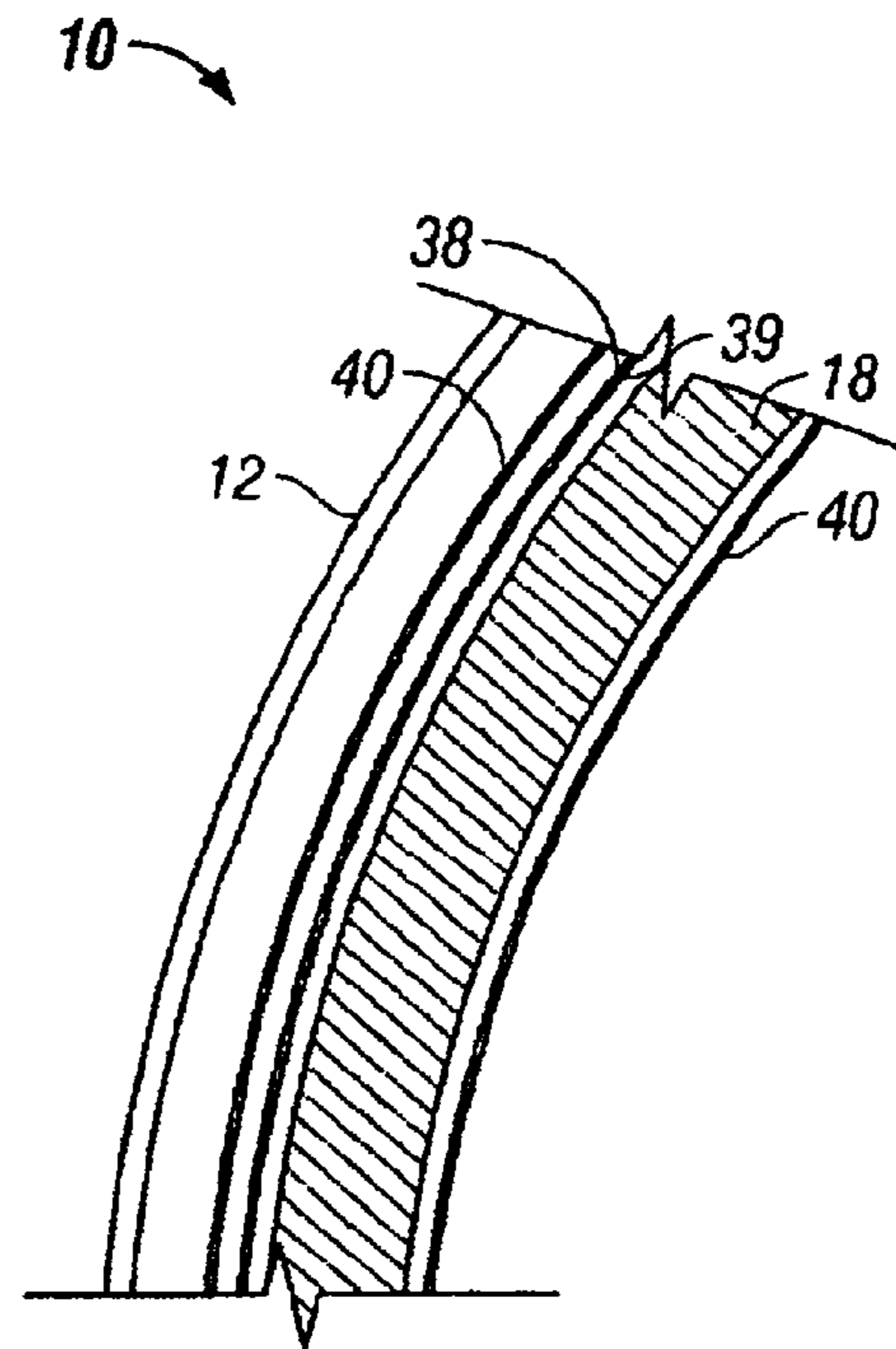


FIG. 16

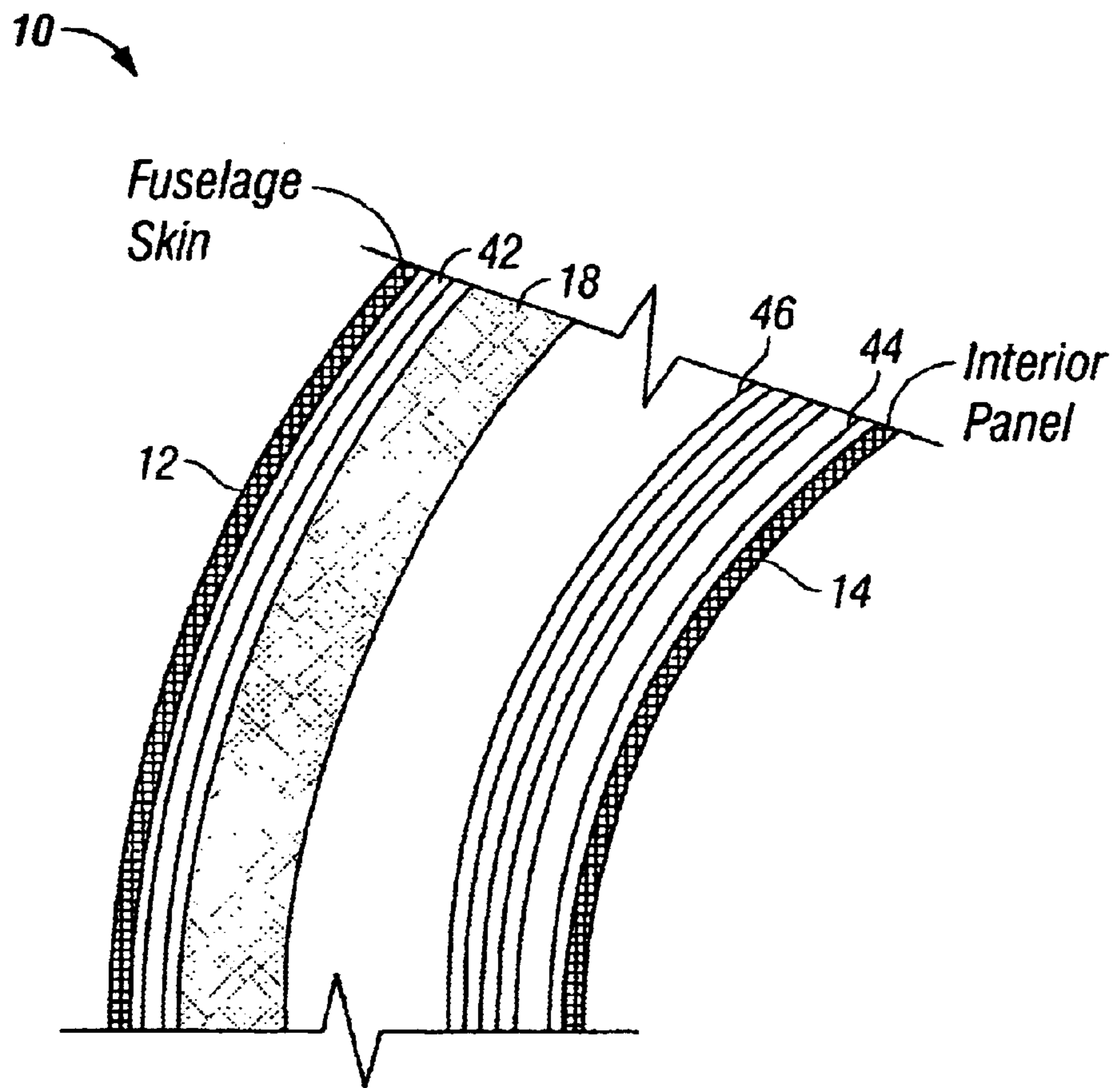


FIG. 17

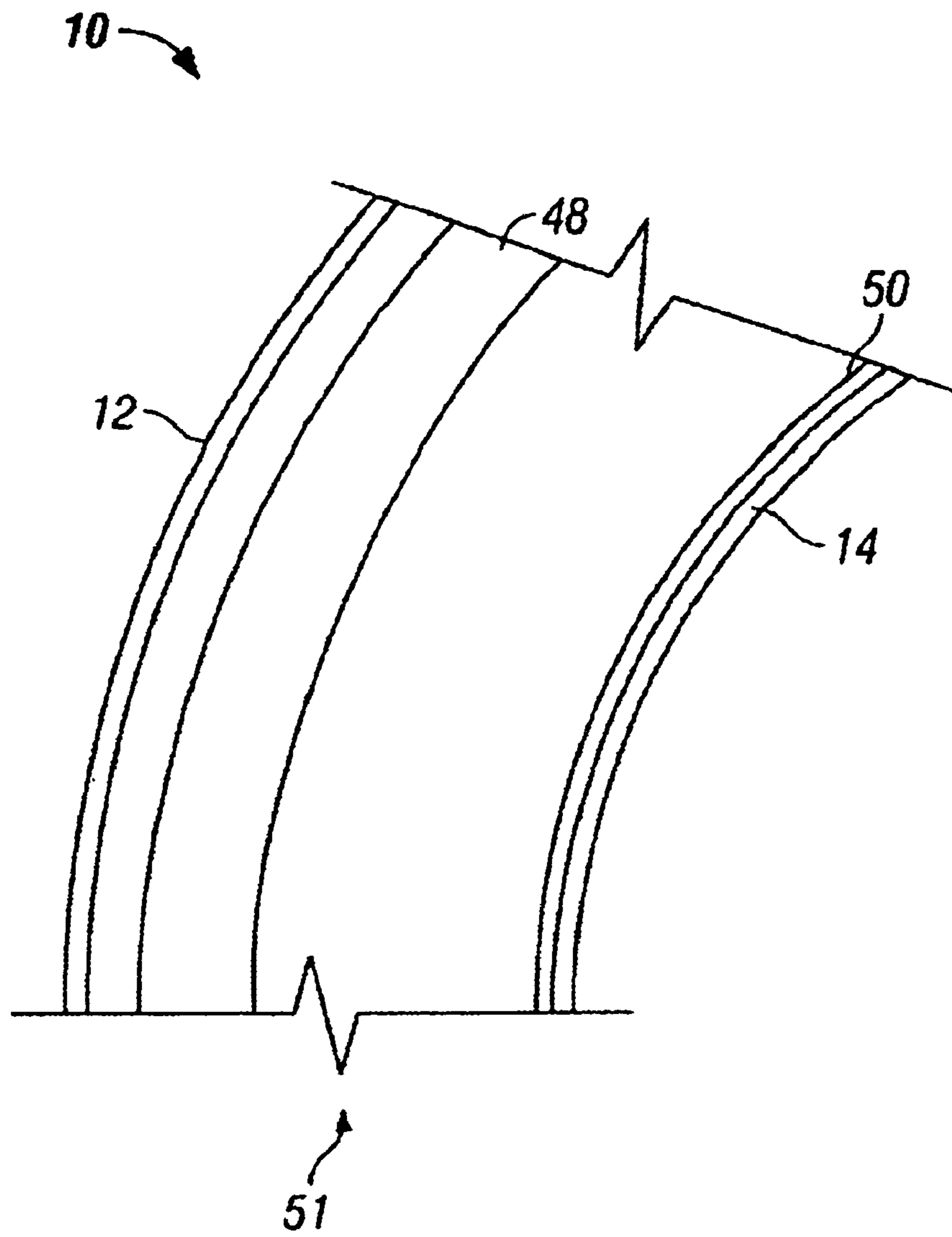


FIG. 18

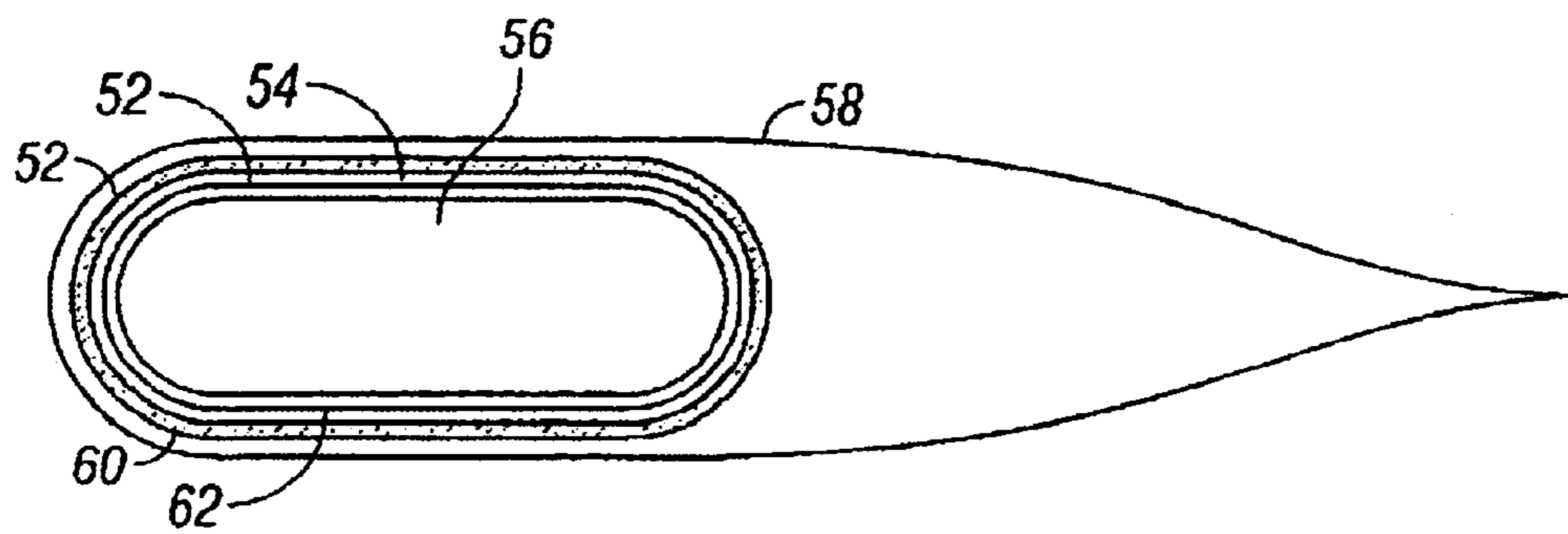


FIG. 19

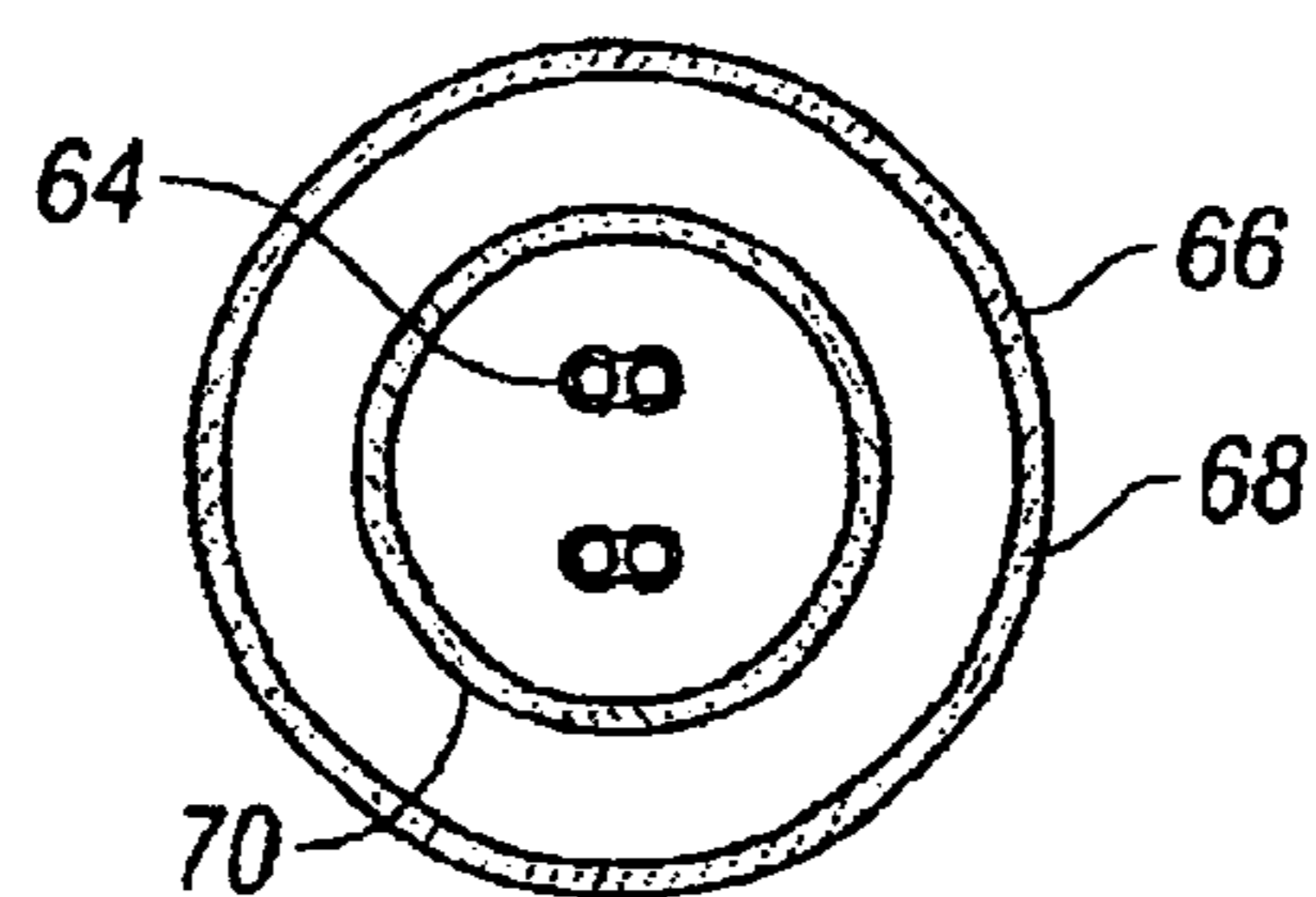


FIG. 20

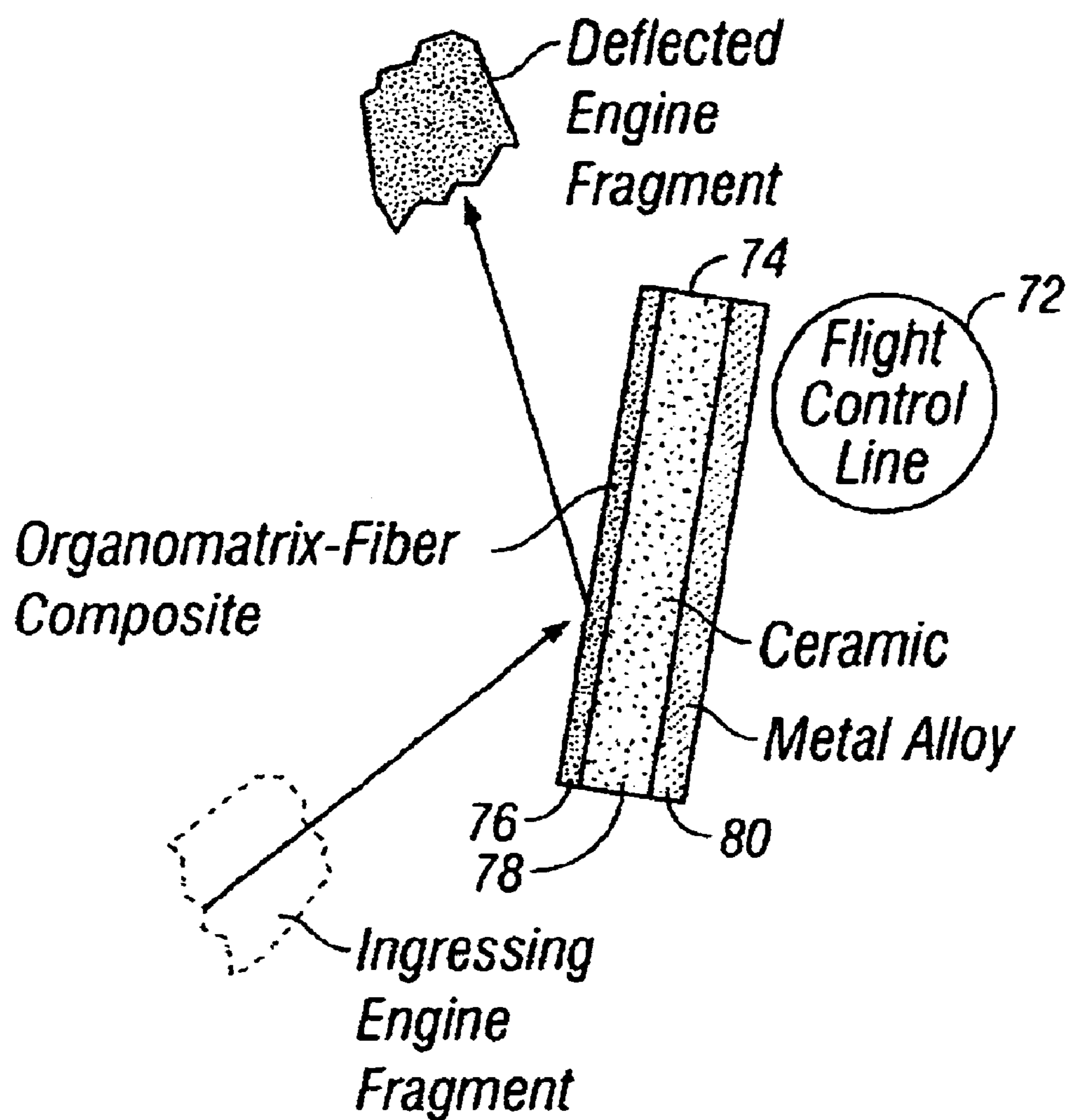
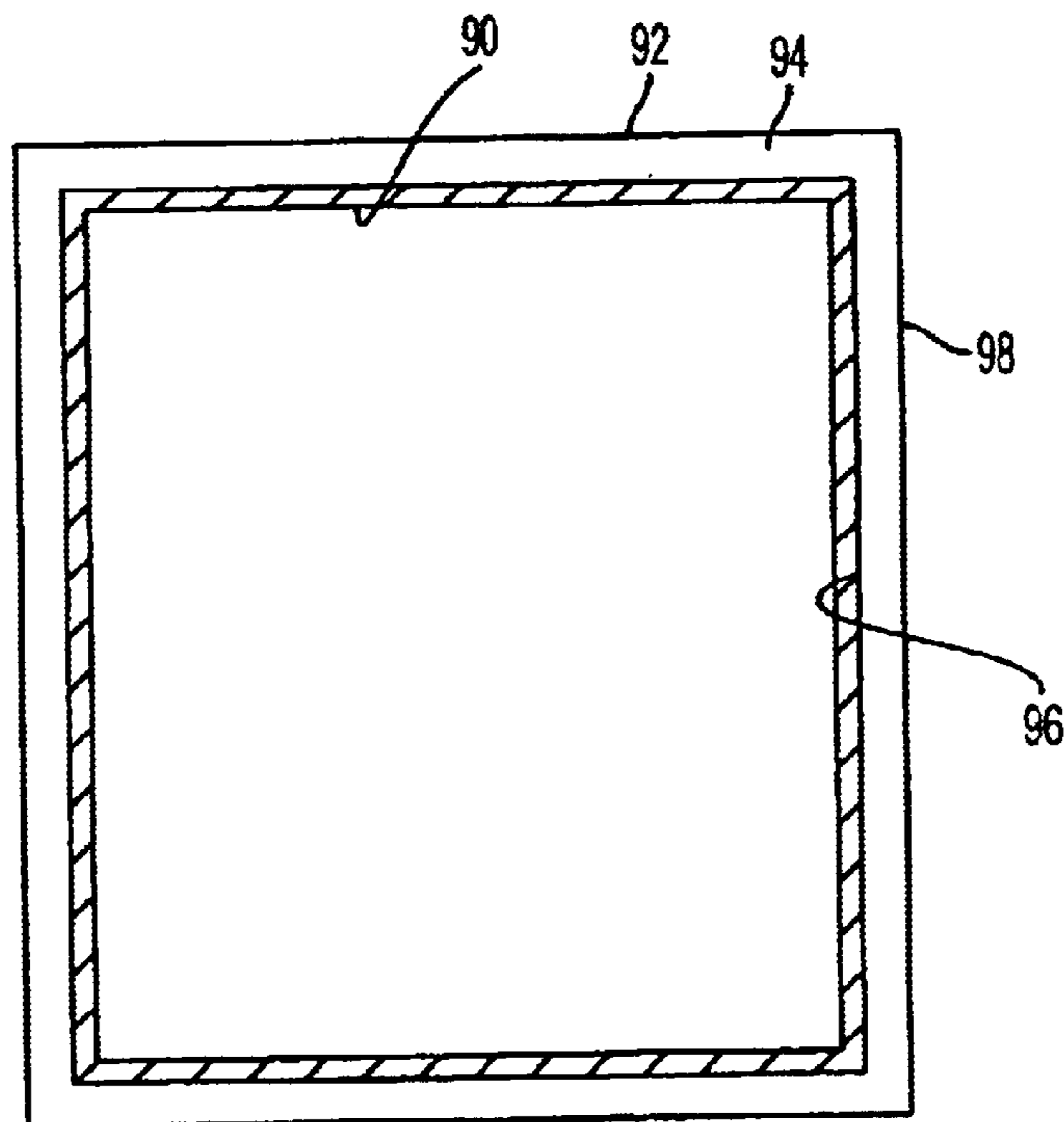
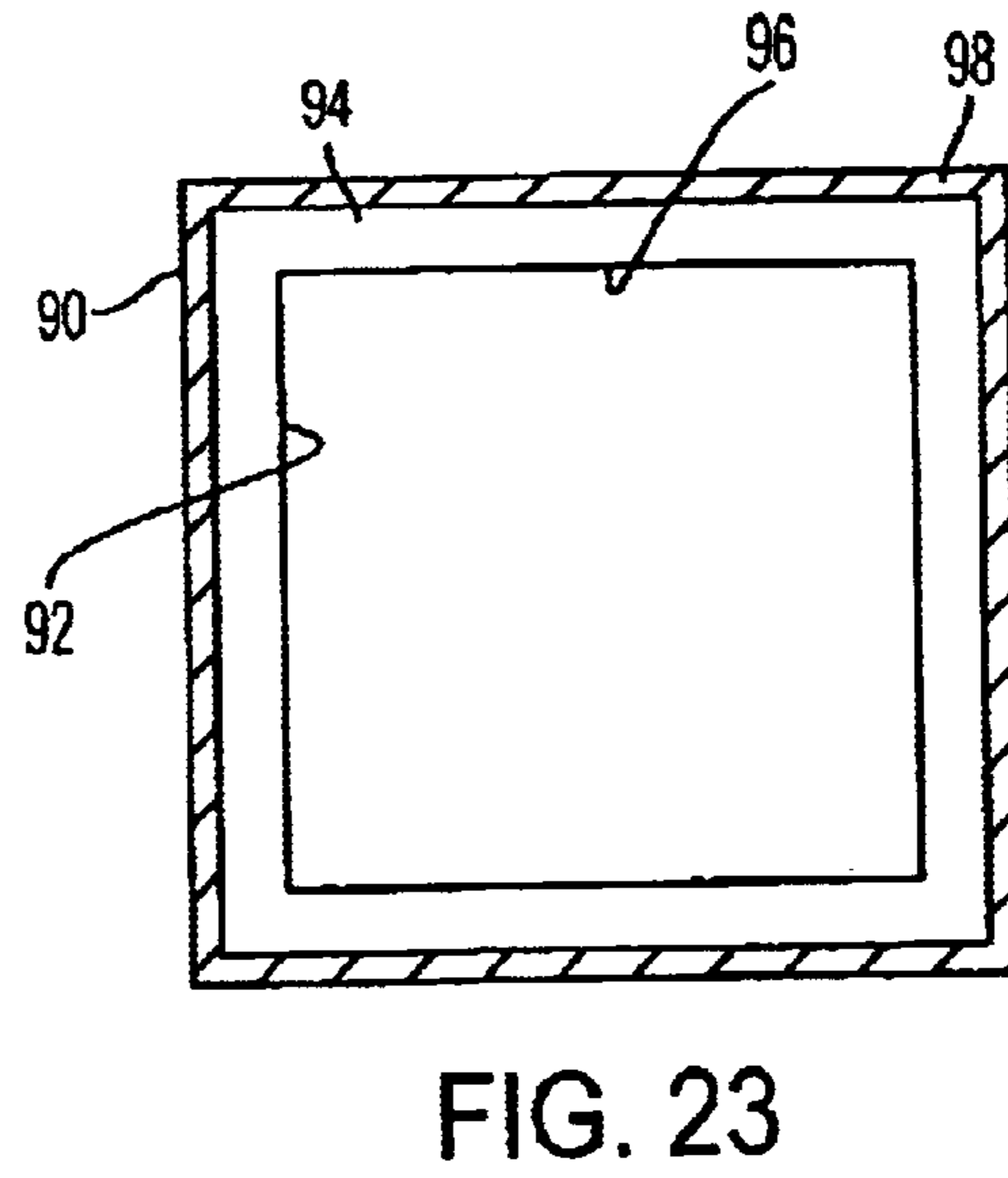
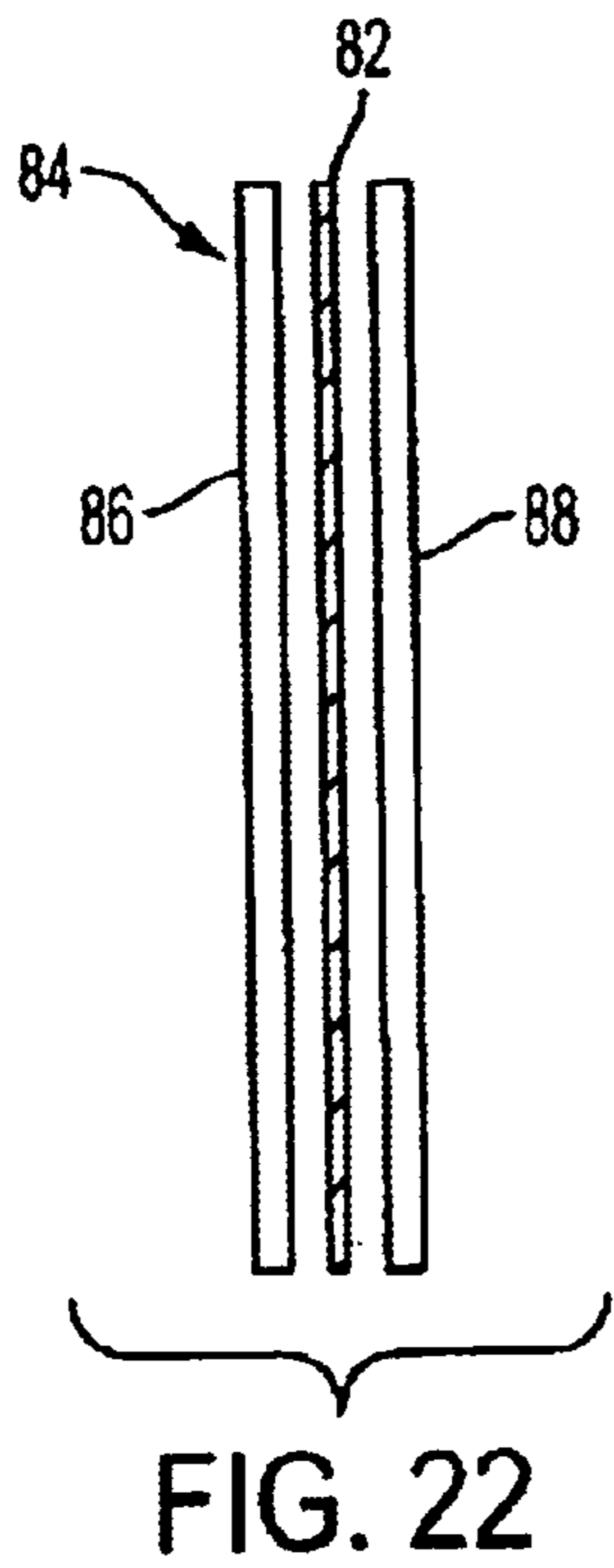


FIG. 21



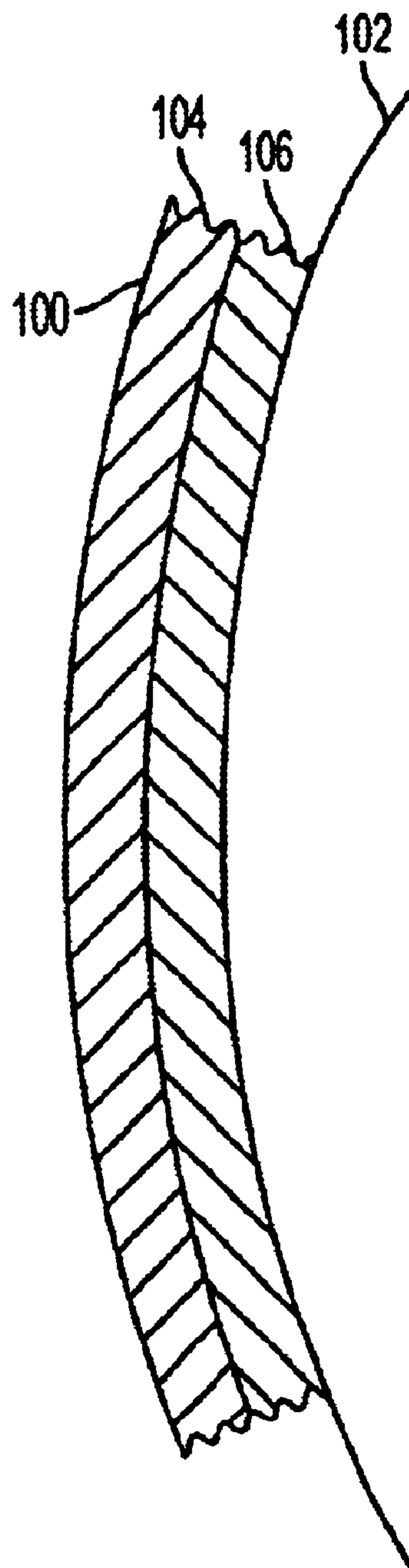


FIG. 25

PENETRATION-AND FIRE RESISTANT FABRIC MATERIALS AND STRUCTURES

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 60/087,771, filed Jun. 2, 1998, and is a continuation of U.S. patent application Ser. No. 09/325,596 entitled Penetration Resistant Fabric Structures and Materials filed Jun. 2, 1999, now U.S. Pat. No. 6,612,217 both of which are incorporated herein by reference for all purposes.

U.S. GOVERNMENT RIGHTS

This invention was made in part with government support under research grant number 95-G-010 awarded by the Department of Transportation, Federal Aviation Administration. The government has certain rights in the invention.

BACKGROUND OF THE INVENTION

1. Technical Field

This invention relates generally to fragment penetration and fire shields, and, more particularly, to penetration and burn-through resistant fabric structures and materials used to absorb energy, arrest projectiles, and act as a fire shield.

2. Description of the Related Art

Over the years several civil aircraft accidents having catastrophic consequences have resulted from damage to critical aircraft components by flying engine fragments produced by an in-flight engine failure. Four systems are critical for continued safe operation and landing of an aircraft: the flight control lines, the fuel lines, the engines, and the pressure boundary. The flight control lines and fuel lines, which are separated spatially in the aircraft and redundant, must not be severed by engine fragments. Likewise, second or third engines need to be operational and thus must not be incapacitated by fragments from a failed engine. Finally, compromise of the pressure boundary (holes and tears in the fuselage wall, for example) at typical cruising altitudes could be catastrophic. The desire to provide ballistic protection at minimum weight and cost and to reduce still further the risk of a catastrophic accident from in-flight engine failure requires low weight with high ballistic properties.

Likewise, several civil aircraft incidents having catastrophic consequences have resulted from combustible material used in insulation blankets and the inability of these materials to act as a fireblock and permit time for passengers to evacuate a burning aircraft. Compounding the problem is the fact that most of the objects inside the aircraft, i.e., seats, walls, bins, are polymeric and may burn and/or decompose into flammable gases when exposed to heat.

Materials supporting combustion were blamed for the Swiss Air incident near Nova Scotia and resulted in a directive by the FAA to replace insulation in all aircraft that contained metallized mylar. Another requirement is for a fire blocker that prevents fire outside the aircraft from penetrating into the cabin for a minimum of 5 minutes to allow evacuation of the occupants.

To mitigate damage caused by projectile penetration, many types of barrier systems have been constructed. Steels have traditionally been the material of choice for land vehicle armor. As shown in FIG. 1a, hard steel surfaces produce large stresses in perpendicularly impacting projectiles, blunting the leading edges and/or breaking them into two or more pieces. Further, as illustrated in FIG. 1b,

steel surfaces are effective in deflecting projectiles striking the surfaces at an angle. Besides their effectiveness in defeating impacting projectiles, steels are inexpensive relative to other materials and are excellent structurally; being weldable, durable, formable, corrosion resistant, compatible with other structural components, and field repairable. The main drawback of steels is their high density, which results in heavy armor structures and renders them especially unsuitable for use in aircraft.

Ceramics have also been used in the construction of barrier systems. Ceramics make good armor and in many instances outperform conventional rolled homogeneous steel armor. High compressive strength allows ceramics to exert large stresses on high speed impacting projectiles, stresses that act to deform, deflect, and fracture the projectile as shown in FIGS. 1a and 1b, as well as eroding the leading edge of penetrating projectiles and eventually reducing them to particles, as illustrated in FIG. 1c. This is very effective against rapidly moving bullets. However, the ability of ceramics to deform, deflect, fracture, and erode a projectile decreases as the velocity of the projectile decreases, because at low projectile velocities fracture of the ceramics occurs at very early times during traverse of the projectile, thereby increasing the probability that the projectile will succeed in piercing the barrier system.

Polymeric fibers are competitive with metals and superior to ceramics at lower projectile velocities. These fibers deform to absorb the kinetic energy of projectiles striking them, slowing or stopping the projectile. However, polymeric barriers used with aircraft have been primarily positioned within the engine nacelle. However, when a rotor disk bursts, the containment structure may be defeated, allowing debris to be projected outwards in the direction of the fuselage and wings.

Likewise, modern ground transportation continues to evolve towards vehicles of lower and lower weight. Demands for speed and maneuverability as well as fuel efficiency require a light vehicle weight. Conversely, impregnability to projectile penetration traditionally required heavy armor, especially for military vehicles. Thus, a trade off must be reached between maintaining a low enough weight to be practical while ensuring protection of critical components and the safety of the passengers.

SUMMARY OF THE INVENTION

This invention relates to a ballistic and/or fire barrier system. More specifically, one embodiment of the invention provides for low weight, high energy absorbing, fire resistant, multiple function structures and materials for superior ballistic protection against projectiles, from munitions and/or fragments of high speed machine components. Another embodiment of the invention resists burn-through to prevent injury to persons and damage to objects behind the barrier from exposure to flame and heat. Most commonly, it is anticipated that the ballistic and/or fire barrier will be used in combination with aircraft. The ballistic and/or fire barrier may also be used with aircraft luggage and cargo containers; limousines; body armor including helmets; shields for back-of-the-armor debris on battle tanks, personnel carriers; or use on or with any other structure or object where protection against projectiles and/or fire is important.

In one embodiment of the present invention, a ballistic barrier protects objects in an interior of a vehicle, such as a land, air, or sea vehicle, from damage due to projectile penetration. The ballistic barrier includes one or more layers

of fabric positioned towards an outer shell of the vehicle. The layer or layers may be disposed in the interior of the vehicle or may be positioned around the outside of the outer shell. The fabric is substantially fixedly or fixedly positioned with respect to the outer shell of the vehicle. If the vehicle includes an inner panel, the layer of fabric can be positioned between the outer shell and inner panel of the vehicle or inside of the inner panel, for example.

As an option, a layer of fabric, alone or in combination with the layer positioned towards the outer shell of the vehicle can be wrapped around at least one component disposed in the interior of the vehicle.

In another embodiment of the present invention, a fire barrier protecting occupants and/or objects in the interior of the vehicle from damage due to heat and contact with flame. The fire barrier has at least one layer of fire resistant fabric disposed in the interior of the vehicle and positioned towards the outer shell of the vehicle. The fire resistant fabric is substantially fixedly positioned with respect to the outer shell of the vehicle.

The layer or layers of fire resistant fabric may comprise a plurality of plies. The layer or layers of fire resistant fabric may also include a fire resistant felt. The layer or layers of fire resistant fabric may comprise a polymer material such as aramid material and/or polybenzoxazole material. One or more layers of either of these two materials may be adequate to resist burn through for the several minutes required for passengers and crew to make an escape from a burning aircraft, particularly in the event of a crash.

In all of the embodiments set forth herein, the fire barrier can be positioned with respect to the recipient object in a similar fashion to the ballistic barrier. Likewise, the fire barrier may be used in conjunction with a ballistic barrier so that both fire resistance and penetration resistance are provided. Furthermore, one layer of fabric, such as one made from aramid material and/or polybenzoxazole material, could provide both fire resistance and penetration resistance.

The vehicle may be primarily designed for military applications, such as the aforementioned tank, for example. Alternatively, the vehicle may be primarily designed for transporting passengers, such as a limousine, armored personnel carrier, etc. The vehicle could also be primarily a cargo vehicle such as a supply truck.

In another embodiment of the present invention, a ballistic barrier protects objects in a structure from damage due to projectile penetration. Such structures include, but are not limited to: buildings; containers such as cargo containers, suitcases, and food containers; etc; or any type of structure capable of partially or fully enclosing an object. The ballistic barrier includes at least one layer of fabric positioned towards an outer housing of the structure. The fabric, which is preferably high strength and/or fire resistant is substantially fixedly positioned with respect to the structure towards either the inner or outer surface of the outer housing. Similarly, a fire barrier may be used to prevent fire and beat damage to objects in a structure.

In yet another embodiment of the present invention, a ballistic barrier protects a wearer of the ballistic barrier from damage due to projectile penetration. The ballistic barrier comprises first and second portions positioned generally parallel each other. The first portion includes at least one layer of fabric, which is preferably high strength and/or fire resistant, while the second portion is constructed of a hard material such that it fractures, deflects, or slows a projectile. Preferably, the first portion is positioned towards the wearer of the ballistic barrier.

In a further embodiment, a ballistic barrier comprised of one or more layers of fabric positioned in the fuselage wall between the outer metal skin and the interior panels and/or around the turbo engines of commercial or private aircraft to prevent engine fragments from penetrating the aircraft fuselage thereby injuring passengers and/or damaging critical aircraft components. The material is resistant to penetration by projectiles, and is designed to absorb kinetic energy of impacting projectiles to slow or stop them. The fabric, which is preferably high strength and/or fire resistant, is fixedly or substantially fixedly positioned with respect to the fuselage of the aircraft. Such ballistic barriers are more optimal in terms of weight, cost, and ease of installation as well as for removal for aircraft inspections.

The layer of high strength and/or fire resistant fabric may comprise a plurality of plies to achieve a desired measure of ballistic resistance. One of the plies may be a felt. Another of the plies may be comprised of woven fibers. The felt has two ballistic functions: to slow the projectile before it strikes a second ply and blanket the sharp edges of the projectile tip to create a larger and blunter leading edge of the projectile, which makes it more difficult for the projectile to penetrate a second ply.

The fabric of the ballistic barrier may be comprised of woven fibers. At least one layer of the fabric can comprise one or more layers of fabric made from high strength and/or fire resistant polymeric fibers such as aramid, ultrahigh molecular weight polyethylene or polybenzoxazole, or a combination thereof, and, optionally, one or more layers of a felt made from these fibers. The felt may be in contact with the fabric layers, or stand off at a distance. The fabric and/or felt may be encapsulated by a water-tight material to prevent moisture absorption.

The fabric can be made of lightweight polymer fibers configured in one of many types of constructs—2- and 3-dimensional weaves, felts, non-wovens, and lay-ups—either singly or assembled in layers or as laminates, in one of many geometries and fiber mixes, and may include metallic or ceramic or composite materials that are resistant to impact and penetration by projectiles such as fragments or bullets.

The layer of fabric may be positioned at various locations in the fuselage with respect to the components of the fuselage. In one embodiment, the ballistic barrier is coupled to one or more of a plurality of frames of the structure of the fuselage of the aircraft to cover the generally open areas of a frame. Projectiles striking the structural beams of the frame are slowed, stopped, or deflected. The ballistic barrier slows or stops projectiles attempting to pass through the substantially open areas of the frame of the structure.

In another embodiment, at least one layer of the ballistic barrier can be coupled to a layer of insulation positioned between the outer skin and inner panel of the fuselage. Alternatively, at least one layer of the ballistic barrier can be enclosed within an outer covering of the layer of insulation. This configuration prevents moisture from being absorbed by the ballistic barrier.

Protection of particular components of the aircraft may be protected by at least one layer of the ballistic barrier wrapped around the component disposed within the aircraft fuselage.

In an embodiment of the present invention, at least one layer of fabric is positioned towards the outer skin of the aircraft and is fixedly or substantially fixedly positioned with respect to the fuselage of the aircraft. This arrangement has the advantage of protecting components found in the fuse-

lage between the inner panel and the outer skin, such as control lines and the like. Further, a projectile will be slowed considerably before striking the inner panel.

The layer of fabric may be coupled to one or more of the frames of the structure of the fuselage. The layer can also be coupled to a layer of insulation or be enclosed within an outer covering of the layer of insulation. This positioning holds the layer away from the outer skin, preventing moisture from being absorbed by the ballistic barrier and corroding the outer skin.

Again it should be noted that in all of the embodiments set forth herein, the fire barrier can be positioned with respect to the recipient object in the same or similar fashion to the ballistic barrier.

Another embodiment of the present invention is designed to provide local protection to inner components of an aircraft, such as fuel and control lines by deflecting a projectile and/or protecting the components from flame and heat. In such an embodiment, the ballistic barrier is constructed of one or more layers of a high strength material that are oriented at an incline relative to an anticipated line of motion of a projectile to deflect the projectile away from the component. Such a barrier would make use of existing aircraft structure, such as longerons, cargo bay floor, and baggage compartment, for mounting. The high strength material may comprise a laminate of one or more of polymer material, ceramic material, and metal alloy. The polymer material should be positioned such that it will be struck by the projectile after the projectile strikes the ceramic or metal alloy so that the polymer material can absorb the energy of any projectile piercing the ceramic and/or metal alloy layers. If all three materials are used, the ceramic material should be positioned between the polymer material and metal alloy.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1a, 1b, 1c, and 1d illustrate projectile defeat mechanisms.

FIG. 2 illustrates the results of a gas gun impact test using targets of a single PBO 30×30 (yarns per inch) mesh weave, tightly gripped on four edges, with and without polyethylene felt.

FIG. 3 illustrates the results of a gas gun impact test using targets of one or more PBO mesh weaves of varying yarns per inch, tightly gripped on four edges, with and without polyethylene felt positioned in front of the weave.

FIG. 4 illustrates the results of a push test of a simulated fan blade and a simulated projectile at varying rates of movement on a single or multiple ply PBO weave with and without one or two plies of PBO felt ungripped and positioned in front of the weave.

FIG. 5 illustrates the results of push tests of a simulated sharp fan blade at a 45 degree angle of movement and moving at 0.075 in./s on a single ply PBO 35×35 weave gripped on four edges with and without one and two plies of PBO felt ungripped and positioned in front of the weave.

FIG. 6 illustrates the results of push tests of a simulated sharp fan blade at a 45 degree angle of movement and moving at 0.075 in./s on a single ply PBO 35×35 weave gripped on two edges with and without two plies of PBO felt ungripped and positioned in front of the weave.

FIG. 7 illustrates the results of push tests of a simulated sharp fan blade at a 45 degree angle of movement and moving at 0.075 in./s on a single ply PBO 35×35 weave gripped on two edges with and without two plies of PBO felt ungripped and positioned in front of the weave.

FIG. 8 illustrates the results of push tests of a simulated sharp fan blade at a 0 degree angle of movement and moving at 0.075 in./s on a single ply PBO 35×35 weave gripped on two edges with and without two plies of PBO felt ungripped and positioned in front of the weave.

FIG. 9 illustrates the results of push tests of a simulated sharpened fragment at a 0 degree angle of movement and moving at 0.075 in./s on a single ply PBO weave gripped on two edges with and without two plies of PBO felt ungripped and positioned in front of the weave.

FIG. 10 is an exploded partial cross sectional view of a typical fuselage of an aircraft.

FIG. 11 illustrates a positioning of several layers of the ballistic and/or fire barrier on the layers of insulation and inner panel of the fuselage of an aircraft.

FIG. 12 illustrates a positioning of one or more layers of the ballistic and/or fire barrier on the structure of the fuselage of an aircraft.

FIG. 13 illustrates a positioning of one or more layers of the ballistic and/or fire barrier towards the outer skin of the fuselage of an aircraft.

FIG. 14 illustrates a positioning of one or more layers of the ballistic and/or fire barrier coupled to the outer skin of the fuselage of an aircraft.

FIG. 15 illustrates a positioning of one or more layers of the ballistic and/or fire barrier towards the outer skin of the fuselage of an aircraft and coupled to the structure.

FIG. 16 illustrates a positioning of one or more layers of the ballistic and/or fire barrier within the outer covering of the layer of insulation of the fuselage of an aircraft.

FIG. 17 illustrates a multi-layer embodiment of the present invention.

FIG. 18 illustrates a multi-layer embodiment of the present invention with felt replacing the layer of insulation.

FIG. 19 illustrates how the ballistic and/or fire barrier may also be used to protect interior components of an aircraft such as a fuel tank.

FIG. 20 illustrates how a component such as a control line disposed within the aircraft fuselage may be protected by wrapping at least one layer of the ballistic and/or fire barrier around the component.

FIG. 21 illustrates an embodiment of the present invention to provide local protection to fuel and control lines.

FIG. 22 illustrates a ballistic and/or fire barrier which protects objects (which includes occupants) in an interior of a vehicle from injury or damage due to projectile penetration and/or fire.

FIG. 23 illustrates a ballistic and/or fire barrier that protects objects (including occupants) in a structure from damage or injury due to projectile penetration and/or fire.

FIG. 24 depicts a ballistic and/or fire barrier that protects objects (including occupants) in a structure from injury or damage due to projectile penetration and/or fire.

FIG. 25 illustrates a ballistic and/or fire barrier that protects a wearer of the barrier from damage due to projectile penetration and/or fire.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The invention includes a low weight, high energy absorbing, fire resistant multiple function barrier for use with vehicles, structures, and other objects for either superior ballistic protection against projectiles, as, for example, from munitions and/or fragments of high speed machine

components or protection from fire or protection from both fire and ballistic penetration.

The ballistic and/or fire barrier may be constructed of fabrics and, optionally, felts, of high-strength polymer fibers or other ballistic materials. In particular, highly ordered, highly crystalline, high-molecular-weight polymers, because of their low density and high strength are the preferred materials because of their low overall weight and high penetration resistance to profile ratio. Specifically, fibers of aramid, polyethylene, and phenylenebenzole (PBO) materials provide the most useful measure of ballistic protection in the most weight-efficient manner. Polyethylene has the advantage of low density but is not particularly flame resistant, though could be made to be more flame resistant through application of a flame retardant to the material. Aramid is more flame resistant, but about 50% more dense than polyethylene. PBO is stronger than either aramid or polyethylene, has high flame resistance, and has density comparable to aramid. A combination of two or all of these ballistic materials may be used to produce one or more layers of fabric or felt. Fire resistant felts may have greater thermal resistance than low-profile layers and thus provide the added advantage of providing greater protection from heat.

The above materials can be configured in one of many types of constructs such as 2- and 3-dimensional weaves, felts, non-wovens, and lay-ups—either singly or assembled in layers or as laminates, in one of many geometries and fiber mixes, and may include metallic or ceramic or composite materials that are resistant to impact and penetration by projectiles such as fragments or bullets. The various layers of materials absorb energy from impacting projectiles through frictional resistance as adjacent fibers slide over one another.

Particular selection and positioning of the layers and felt can be manipulated to produce ballistic and/or fire barriers of varying strength and weight. When creating an arrangement including felt and one or more layers of material, the felt should be positioned such that it will be struck by a projectile before the layer or layers are struck. The felt has two ballistic functions: to slow the projectile and blanket the sharp edges of the projectile tip. As the felt engages the projectile and torn from its lateral fasteners, it deforms substantially, absorbs some energy, and slows the fragment. It does not get penetrated and rides with the projectile to present a larger area, blunter leading edge to the next layer. The felt may also impart some rotation on the projectile. The highest strength/lowest weight felts are constructed by blending fibers of aramids, polyethylenes, PBO, and the like, such as by needle punching to enhance the physical interlocking of crosslapped layers. Further strengthening is attainable by thermobonding, i.e., applying pressure and heat so that one fiber melts and creates a unique bond through out the fabric. It should be kept in mind, however, that the use of felt with the layer or layer of fabrics is optional. Additional layers of woven fabric have projectile-resisting effects similar to a felt layer, and in certain instances may be more weight effective.

An example of such a multi-layered barrier structure showing superior protection against penetration by a projectile was achieved by placing one or two sheets of polyethylene felt in contact with a sheet of PBO fabric and impacting a projectile against the layers. The energy required to penetrate the layers is substantially higher in the presence of the felt than for PBO alone. The improvement provided by the felt results from a combination of three factors, namely, the felt blunts the sharp edges of the

projectile, increases the effective cross-sectional area of the fragment, and increases the drag of the fragment. Specific properties and characteristics of the barrier structures are obtained by varying the number, order, and thickness of the felt and fabric layers, as well as incorporating other materials into the structure. These parameters can be adjusted to maximize performance against specific projectile threats in specific applications.

The number of layers of material and layers of felt will depend on the anticipated size and velocity of the projectile to be protected against. If it is desired to protect against higher energy fragments, the number of layers can be increased or a multilayer of high strength and/or fire resistant polymer fiber could be used. A fabric is considered high-strength herein if it is able to stop a projectile before rupturing or slow a projectile before rupturing.

FIG. 2 illustrates the results of a gas gun impact test using targets of a single PBO 30×30 (yarns per inch) mesh weave, tightly gripped on four edges, with and without polyethylene felt. The felt was ungripped and positioned in front of the weave. As shown, the use of one ply of felt nearly doubled the amount of kinetic energy lost by the projectile (FS). When the felt was used, the projectile did not penetrate the felt, but completely penetrated the fabric still surrounded by the felt. When two plies of felt were used, the projectile, surrounded by the felt, remained lodged in a hole in the weave.

FIG. 3 illustrates the results of a gas gun impact test using targets of one or more PBO mesh weaves of varying yarns per inch, tightly gripped on four edges, with and without polyethylene felt positioned in front of the weave. The felt was ungripped and positioned in front of the weave. Again it is seen that the use of felt is very effective in slowing or stopping the projectile. In both tests where the felt was used, the projectile did not pierce the felt.

FIG. 4 illustrates the results of a push test of a simulated fan blade (FB) and a simulated projectile (FS) at varying rates of movement on a single or multiple ply PBO weave with and without one or two plies of PBO felt ungripped and positioned in front of the weave. The simulated fan blade and projectile were oriented at varying angles to the weave. The use of felt greatly increased the load required to break a first yarn of the weave. Further, the load which could be handled by the combination of the weave and the felt was much greater than the weave itself.

FIGS. 5 through 9 illustrate the results of push tests of a simulated sharp fan blade or a simulated sharp projectile at various angles of movement on a single ply PBO weave with and without one or two plies of PBO felt ungripped and positioned in front of the weave. As shown, the use of felt greatly increases the distance which a projectile will be allowed to travel before penetrating the weave, as well as increases the load required to penetrate the weave.

Examples of specific anticipated uses of the ballistic and/or fire barrier include, but are not limited to, ballistic and/or fire barriers on aircraft; aircraft luggage and cargo containers; VIP limousines; body armor including helmets; shields for back-of-the-armor debris on battle tanks, personnel carriers; or use on or with any other object where protection against projectiles is important.

FIG. 10 illustrates a portion of a fuselage 10 of an aircraft that has an outer skin 12, an inner panel 14, a structure 16 positioned between the outer skin and the inner panel, and a layer of insulation 18, which may be positioned between the inner panel and the structure 16 or between the outer skin 12 and the structure 16. Depending on aircraft type, up to 4

to 5 inches of space exists between the outer skin **12** and the inner panel **14** of the fuselage **10**. The structure **16** may have a plurality of frames **20** coupled together to form the overall structure **16**. See FIG. **11**. Together, the frames create a grid of thicker, more fragment-resistant metallic structural beams **22** encompassing roughly 9 by 20 inch generally open areas. In these generally open areas, only the outer skin **12**, the layer of insulation **18**, and the inner panel **14** are in the path of an engine fragment. These areas offer little resistance to penetration from fragments and any critical component behind the area would be impacted with nearly the entire energy of the fragment.

FIG. **11** illustrates a first application of the present invention designed to enhance the survivability of commercial and military aircraft in the event of an uncontained turbine engine failure, impact of projectiles from any source, and/or fire. One or more layers of high strength and/or fire resistant fabric **24**, **26**, which together form the ballistic and/or fire barrier **27**, are substantially fixedly positioned between the outer skin **12** and the inner panel **14** of the fuselage **10**. The layers **24** plastically deform to absorb the kinetic energy of low-energy projectiles, which prevents the projectiles from penetrating the fuselage wall and then severing control lines, injuring passengers, or entering and exiting the fuselage **10** and damaging a second engine.

Constraints such as window positioning and points of coupling of the various components of the fuselage **10** requires that noncritical areas be left unprotected. Therefore, as shown in FIG. **11**, the ballistic and/or fire barrier **27** can be positioned to slow or stop projectiles that strike the substantially open areas within the grid boundaries of the structure **16**. Fire protection can also be enhanced in such locations. For example, smaller sized layers **24** may be coupled to the layer of insulation **18** to slow or stop projectiles that penetrate the fuselage **10** skin. Alternatively or in combination with the layers **24** coupled to the layers of insulation as an added measure of protection, larger sized layers **26** may be positioned toward or coupled to the inner panel **14** of the fuselage **10**. Any projectile that breaches the smaller sized layers **24** strikes the larger sized layers **26** with greatly reduced energy.

FIG. **12** illustrates another embodiment of the present invention. Layers **28** of the ballistic and/or fire barrier **29** are attached to the frames **20** of the structure **16**. The layers **28** can be positioned to cover the generally open areas of the frames **20**. Projectiles striking the structural beams **22** of the structure **16** are slowed, stopped, or deflected. The layers **28** slow or stop projectiles attempting to pass through the substantially open spaces of the frames **20** of the structure **16**.

In a configuration where the ballistic and/or fire barrier **29** is positioned between the outer skin **12** and layer of insulation **18** of the fuselage **10**, as in the embodiment shown in FIG. **12**, the layer or layers **28** of the ballistic and/or fire barrier **29** engage the projectile or resist a flame after it penetrates the outer skin **12** of the fuselage **10**. The high tensile strength and cut resistant properties of the ballistic fabric resist penetration by the projectile, so that the layer or layers **28** of the ballistic and/or fire barrier along with the layer of insulation **18** are pulled in the direction of the projectile, their mass and bulk exerting drag loads on the projectile and slowing it. As the projectile contacts the inner panel **14** of the fuselage **10**, it is slowed and has a blunted edge because of the fabric and insulation draped over it. The inner panel **14** resists the draped projectile and may stop its progress or be penetrated. In the later situation, the fabric and insulation will begin to be pulled through the hole in the

inner panel **14**, exerting additional drag as the draping **10** material is resisted by friction at the hole periphery. The projectile may be stopped after modest ingress into the passenger cabin, or in the case of a sufficiently energetic projectile, may continue with reduced velocity. The stopping power of the inner panel **14** may be enhanced as desired by coupling a layer or layers **30** of ballistic fabric to the outboard side of the inner panel **14**.

In FIG. **13** yet another embodiment of the present invention is illustrated. A layer or layers **32** of the ballistic and/or fire barrier **33** are positioned towards the outer skin **12** of the fuselage **10**. This configuration provides greater protection to interior components of the aircraft, such as fuel and control lines. Further, this arrangement is especially adapted to provide resistance to projectile penetration and fire into nonpassenger portions of the aircraft which may or may not have inner panels **14** such as, for example, cargo areas and landing gear bay doors.

The ballistic and/or fire barrier may be substantially fixedly positioned with respect to the fuselage **10**, or may be fixedly coupled to the components of the fuselage **10** such that it is fixedly positioned with respect to the outer skin **12** or structure **16**. A layer **34** of the ballistic and/or fire barrier **35** may be detachably or fixedly coupled directly to the outer skin **12** of the fuselage **10** as shown in FIG. **14**. An advantage of coupling the layers **34** of the ballistic and/or fire barrier **35** directly to the outer skin **12** of the fuselage **10** is to conserve the pressure boundary. Such an arrangement minimizes the areas of perforation and prevents widespread tearing of the outer skin **12**. Alternatively, the layer **36** may be coupled to the frames **20** of the structure **16** as shown in FIG. **15**. The layer **36** should be coupled to the structure **16** close to the outer skin **12** but separated from it by a small distance so as not to trap moisture against the outer skin **12** and cause corrosion.

In FIG. **16**, a layer **38** of the ballistic and/or fire barrier **39** is positioned within an outer covering **40** of a layer of insulation **18** positioned towards the outer skin **12** of the fuselage **10** (i.e., with the layer **38** positioned towards the outer skin **12**). This configuration has the advantage of preventing absorption of condensation by the layer **38**. The outer covering **40** acts as a barrier to moisture that condenses on the various components of the fuselage **10**. To obtain an additional increment of ballistic resistance, the outer covering **40** of the layer of insulation **18** could be one or more layers of a strong impervious-to-water material such as a bonded fiber layup.

FIG. **17** illustrates a multi-layer embodiment of the present invention. Felt **42** is used in combination with a layer of high strength and/or fire resistant fiber layup **44**. The felt **42** is positioned on an outer side of the layer of insulation **18**. The layer of high strength and/or fire resistant fiber layup **44** is positioned adjacent the inner panel **14**. If desired to stop fragments of high velocity which could penetrate both the felt **42** and the layer of high strength and/or fire resistant fiber layup **44**, several layers of ballistic fabric **46** may be positioned between the layer of insulation **18** and the layer of high strength and/or fire resistant fiber layup **44**. The felt **42** should be coupled to the structure **16** close to the outer skin **12** but separated from it by a small distance so as not to trap moisture against the outer skin **12** and cause corrosion.

There are several methods to substantially fixedly position the layers of the ballistic and/or fire barrier with respect to the fuselage **10**. For example, the layers may be held in place by Friction such as being pinched between two components

of the fuselage **10**. One example would be positioning a layer between a layer of of the fuselage **10**. Exemplary existing components of the fuselage **10** are the layer of insulation **18** and the inner panel **14**. Their replacement with the ballistic and/or fire barrier thus requires the ballistic and/or fire barrier to provide adequate thermal insulation, acoustic insulation, flame resistance, moisture resistance, and aesthetics. From the standpoint of fire, three issues are critical: flammability, smoke production, and toxicity of the gas produced.

Aramid and PBO materials have moderate to high flame resistance, water absorption resistance, and thermal and acoustic insulation properties to serve as such building materials for multi purpose ballistic and/or fire barriers. Also, as aforementioned, polyethylene materials can be made sufficiently fire resistant through application of a flame retardant.

As shown in FIG. **18**, as an example, felt **48** replaces the current insulation material. It should be noted that the felt **48** can be used to replace only a portion of the insulation material as well. A layer of high strength and/or fire resistant material **50** may be positioned along the inner panel **14** of the fuselage. As another example, the inner panel **14** of the fuselage **10** may be constructed of a projectile resistant polymeric material, such as one or more of aramid, polyethylene, and PBO, so that the inner panel **14** forms part of the ballistic and/or fire barrier **51**.

The ballistic and/or fire barrier may also be used to protect interior components of an aircraft, especially in portions of the aircraft where moving parts makes attachment of the ballistic and/or fire barrier difficult or impossible. For example, in FIG. **19**, the layers **52** of the ballistic and/or fire barrier **54** surrounds a fuel tank **56** in a wing **58** of the aircraft. In this exemplary embodiment, felt **60** may or may not surround a layer of ballistic material **62**. A projectile striking the ballistic and/or fire barrier **54** would be slowed or stopped by the ballistic and/or fire barrier before striking the tank. In the event that the projectile does pierce the fuel tank **56**, the felt **60** acts as an insulator to prevent the projectile from creating a spark that could ignite the fuel in the fuel tank **56** as well as helps slow leakage from the insulation **18** and the structure **16** of the fuselage **10** and pressing the insulation against the structure **16** such that the layer will not be substantially repositioned by vibration from travel or weight due to water absorption. In another example, a layer may be positioned inside an outer covering of the insulation between the outer covering and the insulating material, as discussed above. Also, corners and/or edges of the layers may be detachably coupled to an adjacent object. In any case, when only one or more layers of fabric are used, the layers should load the projectile as much as possible, but should break free of any coupling and be allowed to travel with the projectile before the projectile pierces the layers. The mass of the layers will continue to exert drag on the projectile. Further increasing the drag would be the friction exerted on the layers caused by the projectile dragging the layers through an aperture in an adjacent structure.

Alternatively, when used with a layer of felt, a layer of fabric may be fixedly coupled to the component of the fuselage **10** to which the layer is most closely positioned. An adhesive may be used to attach the layer to the components of the fuselage **10**. Further, the layer may be coupled to the components of the fuselage **10** with fasteners. Irregardless of the method used to hold the layers in place, the layers should be held sufficiently in place so that they can absorb the energy of the projectile without being pulled along with the

projectile more than is necessary to slow or stop the projectile. However, it should be noted that any layer of felt should be allowed to become detached from the fuselage **10** so that it may travel with the projectile, thus blunting the projectile and traveling with the projectile to continue to exert drag on the projectile even though the projectile pierces through the layer of fabric.

As an option, the added weight and cost of insertion of the ballistic and/or fire barrier may be minimized by replacing existing materials in the fuselage **10** wall with dual function ballistic materials. The ballistic and/or fire barrier may be constructed of materials having high specific ballistic protection that can simultaneously perform the functions of, and perhaps replace, existing components newly created hole. Other exemplary internal components of the aircraft that could be protected include computers and other electronic equipment, hydraulics, and the like.

FIG. **20** illustrates how a component **64** such as a control line disposed within the aircraft fuselage may be protected by wrapping at least one layer **66** of the ballistic and/or fire barrier **68** around the component **64**. The high strength of the layer **66** helps prevent a projectile from piercing the outer covering **70** of the component **64**. The layer **66** may be wrapped loosely around the component to urge deflection of an impacting projectile.

FIG. **21** illustrates another embodiment of the present invention to provide local protection to inner components **72** of an aircraft, such as fuel and control lines. Fuel lines and flight control lines, whether hydraulic, mechanical, wire, or optical, are likely to be most efficiently protected by local ballistic and/or fire barriers **72** positioned near the line and in the path of the expected fragment trajectory. In such an embodiment, the ballistic and/or fire barrier **74** is constructed of one or more layers of a high strength material that are oriented at an incline relative to an anticipated line of motion of a projectile to deflect the projectile away from the component **72**. Such a ballistic and/or fire barrier **74** could make use of existing aircraft structure, such as longerons, cargo bay floor, and baggage compartment, for mounting.

The high strength and/or fire resistant material should comprise a laminate of one or more of polymer material **76**, ceramic material **78**, and metal alloy **80**. The polymer material **76** can be constructed in a weave, ply, or any other configuration. In an embodiment where the layer of high strength and/or fire resistant material comprises a laminate of polymer material **76** with a ceramic material **78** and/or metal alloy **80**, the polymer material **76** should be positioned such that it will be struck by the projectile first. In an embodiment where the layer of high strength and/or fire resistant material comprises a laminate of ceramic material **78** and metal alloy **80**, the ceramic material **78** should be positioned such that it will be struck by the projectile first. If all three materials are used, the ceramic material **78** should be positioned between the polymer material **76** and metal alloy **80**.

FIG. **22** illustrates a ballistic and/or fire barrier **82** which protects objects such as occupants, components, cargo, etc. in an interior of a vehicle **84**, such as a land, air, or sea vehicle, from damage or injury due to projectile penetration and/or fire. It must be stressed that the term "objects" as used herein can refer to occupants as well as other things sought to be protected. The ballistic and/or fire barrier **82** includes one or more layers of high strength and/or fire resistant fabric positioned towards an outer shell **86** of the vehicle. The layer or layers may be disposed in the interior of the vehicle **84** or may be positioned around a portion or all of the

outside of the outer shell **86** of the vehicle **84**. The high strength and/or fire resistant fabric is substantially fixedly or fixedly positioned with respect to the outer shell **86** of the vehicle **84** to prevent its sliding during travel and to create a load on an impacting projectile. If the vehicle **84** includes an inner panel **88**, the layer of high strength and/or fire resistant fabric can be positioned between the outer shell **86** and an inside of the inner panel **88** of the vehicle **84** or towards an outside of the inner panel **88**. It is to be understood that the material presented in the foregoing paragraphs with respect to the ballistic and/or fire barrier and its use with aircraft is also applicable to this and the following embodiments.

The vehicle **84** may be primarily designed for military applications, such as a tank, gunboat, or jet fighter for example. Alternatively, the vehicle **84** may be primarily designed for transporting passengers, such as a limousine, armored personnel carrier, etc. The vehicle **84** could also be primarily designed for transporting cargo, such as a supply truck.

Optionally, alone or in combination with a ballistic and/or fire barrier positioned towards the outer shell **86** of the vehicle **84**, a layer of high strength and/or fire resistant fabric can be wrapped around at least one component disposed in the interior of the vehicle **84**.

FIGS. **23** and **24** illustrate a ballistic and/or fire barrier **90** that protects objects (including occupants) in a structure **92** from damage or injury due to projectile penetration and/or fire. Such structures include, but are not limited to: buildings; containers such as cargo containers, suitcases, and food containers; etc; or any type of structure capable of partially or fully enclosing an object. The ballistic and/or fire barrier **90** includes at least one layer of high strength and/or fire resistant fabric positioned towards an outer housing **94** of the structure **92**. The high strength and/or fire resistant fabric is substantially fixedly positioned with respect to the structure **92** towards either or both the inner surface **96** or outer surface **98** of the outer housing **94**. It should be kept in mind that the ballistic and/or fire barrier **90** does not have to cover all of the outer case **94**, but may only cover a portion of it, such as a portion of the outer housing **94** deemed most likely to be impacted by a projectile.

FIG. **23** depicts the ballistic and/or fire barrier **90** positioned towards the outer surface **98** of the structure **94**. Such an embodiment aids in the prevention of the projectile piercing the structure **92** by loading the projectile as it impacts the structure, then blunting the object as it attempts to pierce the outer housing **94**. Finally, the ballistic and/or fire barrier **90** will travel with the projectile if it pierces the outer housing **94**, loading the projectile as the barrier **90** is slowed by friction as it is pulled through the hole in the outer housing **94**. It should be kept in mind that the ballistic and/or fire barrier **90** may break free of the structure **92**.

FIG. **24** illustrates the ballistic and/or fire barrier **90** positioned towards the inner surface **96** of the structure **94**. Such an embodiment aids in the arrest of a projectile that penetrates the structure **92** or pieces of the outer housing **94** broken free by the projectile. Preferably, the ballistic and/or fire barrier **90** will break free of the inner surface **96** of the structure **92** before the projectile pierces the barrier **90** to blunt the projectile.

In yet another embodiment of the present invention, shown in FIG. **25**, a ballistic and/or fire barrier **100** protects a wearer **102** of the ballistic and/or fire barrier **100** from damage due to projectile penetration and/or fire. The ballistic and/or fire barrier **100** comprises first and second portions

104,106 positioned generally parallel each other. The first portion **104** includes at least one layer of high strength and/or fire resistant fabric, of a type set forth above. The second portion **106** should have a high hardness to deflect, fracture, slow, stop or otherwise resist an impacting projectile. Preferably, the second portion **106** not only resists penetration by the projectile, but also spreads the shock of impact over a greater area of the wearer's body. Preferably, the first portion **104** is positioned between the wearer of the ballistic and/or fire barrier **100** and the second portion **106**.

In all of the embodiments set forth herein, the fire barrier can be used interchangeably or in combination with the ballistic barrier. Furthermore, one layer of fabric, such as one made from aramid material and/or polybenzoxazole material, could provide both fire resistance and penetration resistance.

Although the invention is described herein with reference to several preferred embodiments, one skilled in the art will readily appreciate that permutations, substitution, additions and equivalents may be substituted for the embodiments set forth herein without departing from the spirit and scope of the present invention. It is therefore intended that the following appended claims be interpreted as including all such permutations, substitutions, additions, and equivalents as fall within the true spirit and scope of the present inventions.

What is claimed is:

1. A ballistic barrier preventing penetration by a foreign body in combination with an outer shell of an aircraft, the outer shell defining the interior of the aircraft, the ballistic barrier in combination with the outer shell comprising:

at least one layer of fabric disposed in the interior of the aircraft, wherein the at least one layer of fabric is capable of absorbing kinetic energy of the foreign body, the at least one layer of fabric being substantially positioned towards the interior of the aircraft with respect to the outer shell and at a finite distance away from the outer shell, and wherein the at least one layer of fabric is composed of one or more ballistic material selected from a group consisting of aramid, polyethylene and phenylenebenzole, and wherein the at least one layer of fabric includes at least two plies and wherein one of the plies is felt.

2. The ballistic barrier as recited in claim **1**, wherein the felt being positioned outward of the remaining plies with respect to the interior.

3. The ballistic barrier as recited in claim **1**, wherein at least one of the plurality of plies includes woven fibers.

4. The ballistic barrier as recited in claim **1**, wherein the at least one layer of fabric is fire resistant.

5. The ballistic barrier as recited in claim **1**, wherein the foreign body includes projectile or fragment munitions.

6. The ballistic barrier as recited in claim **1**, wherein the aircraft includes an inner panel, and wherein the at least one layer of fabric is positioned between the outer shell and the inner panel of the aircraft.

7. A ballistic barrier in combination with an outer housing of a structure, the outer housing defining an interior, for protecting objects in the interior of the structure from damage, the ballistic barrier in combination with said outer housing comprising:

two or more layers of fabric disposed in the interior of the structure, the two or more layers of fabric being substantially positioned towards the outer housing of the structure and at a finite distance away from said outer housing of the structure, wherein at least one layer of fabric is capable of absorbing kinetic energy of a foreign body; and

15

wherein a first of the two or more layers of fabric is a felt, the felt being positioned toward the outer housing of the structure with respect to the other layers of fabric.

8. The ballistic barrier as recited in claim 7, wherein at least one of the two or more layers of fabric is composed of one or more ballistic material selected from a group consisting of aramid, polyethylene and phenylenebenzole.

9. The ballistic barrier as recited in claim 7, wherein one of the two or more layers of fabric is fire resistant.

10. The ballistic barrier as recited in claim 7, wherein the structure includes a vehicle.

11. The ballistic barrier as recited in claim 7, wherein the structure includes an aircraft.

12. A method for protecting objects in an interior of a structure from damage, the structure having an outer shell defining the interior of the structure, the method comprising:

positioning at least one layer of fabric in the interior of the structure towards the outer shell of the structure and at a finite distance away from the outer shell, wherein the at least one layer of fabric is capable of absorbing a kinetic energy of a fragment or a projectile; and

attaching the at least one layer of fabric to the structure such that the at least one layer of fabric is substantially positioned towards the interior of the structure with respect to the outer shell and at a finite distance away from the outer shell such that upon impact from the fragment or the projectile the fabric tends to detach from the structure, the at least one layer of fabric composed of one or more ballistic material selected from a group consisting of aramid, polyethylene and phenylenebenzole;

wherein the at least one layer of fabric includes a plurality of plies;

wherein one of the plurality of plies is a felt, the felt being positioned outward of the remaining plies with respect to the interior.

13. A ballistic fire barrier in combination with a vehicle, the vehicle having an outer shell defining an interior, the ballistic fire barrier in combination with the vehicle comprising:

two or more layers of fire resistant fabric disposed in the interior of the vehicle and substantially fixedly positioned towards the interior of the vehicle with respect to the outer shell of the vehicle and at a finite distance away from the outer shell, wherein a first of the two or more layers of fire resistant fabric is capable of absorbing kinetic energy of a fragment or a projectile and a second of the two or more layers of fire resistant fabric is a felt, the second layer being positioned outward of the first layer with respect to the interior of the vehicle.

14. The ballistic fire barrier as recited in claim 13, wherein at least one of the two or more layers of fire resistant fabric includes a plurality of plies.

15. The ballistic fire barrier as recited in claim 13, wherein at least one of the two or more layers of fire resistant fabric

16

is composed of one or more ballistic material selected from a group consisting of aramid, polyethylene and phenylenebenzole.

16. The fire barrier as recited in claim 13, wherein the fire resistant fabric is detachably fixed to a frame disposed between the outer shell and an inner panel such that upon impact from the fragment or the projectile the fire resistant fabric tends to detach from the frame.

17. The ballistic fire barrier as recited in claim 13, wherein the vehicle includes an inner panel, and wherein the two or more layers of fire resistant fabric are positioned between the outer shell and the inner panel of the vehicle.

18. The ballistic fire barrier as recited in claim 13, wherein the vehicle is an aircraft.

19. A method for protecting objects in an interior of a vehicle from damage and injury, the vehicle having an outer shell defining the interior of the vehicle, the method comprising:

positioning at least one layer of fire resistant fabric in the interior of the vehicle towards the outer shell of the vehicle with respect to the interior of the vehicle;

attaching the at least one layer of fire resistant fabric to the vehicle such that the at least one layer of fire resistant fabric is substantially positioned at a finite distance away from the outer shell of the vehicle, the at least one layer of fabric capable of absorbing kinetic energy of a fragment or a projectile and composed of one or more ballistic material selected from a group consisting of aramid, polyethylene and phenylenebenzole, and wherein the at least one layer of fabric includes at least two plies and wherein one of the plies is felt; and wherein the vehicle is an aircraft.

20. A method for protecting objects in an interior of a vehicle from damage and injury, the vehicle having an outer shell defining the interior of the vehicle, the method comprising:

positioning at least one layer of fire resistant fabric in the interior of the vehicle towards the outer shell of the vehicle with respect to the interior of the vehicle;

attaching the at least one layer of fire resistant fabric to the vehicle such that the at least one layer of fire resistant fabric is substantially positioned at a finite distance away from the outer shell of the vehicle, the at least one layer of fabric capable of absorbing kinetic energy of a fragment or a projectile and composed of one or more ballistic material selected from a group consisting of aramid, polyethylene and phenylenebenzole; and

wherein the at least one layer of fire resistant fabric includes two or more plies, a first of the two or more plies being a felt and a second of the two or more plies including woven fibers, the first of the two or more plies being positioned outward of the second of the two or more plies with respect to the interior of the vehicle.

* * * * *